BUCKMASTER'S ANIMAL PHYSIOLOGY

Thos. J. Barnardo
London '67

BUCKMASTER'S ELEMENTS

OF

ANIMAL PHYSIOLOGY

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LONDON

LONGMAN AND CO.; SIMPKIN, MARSHALL, AND CO.

DUBLIN: M. AND J. SULLIVAN, 27, MARLBOROUGH STREET

AND ALL BOOKSELLERS

MDCCCLXVI

J. & W. Rider, Printers, 14, Bartholomew Close, London, E.C.

TO

MR. ALDERMAN ROBERT RUMNEY, F.C.S.,

WHOM HE HAS LONG KNOWN AS A WARM AND SINCERE ADVOCATE OF POPULAR EDUCATION AND SCIENTIFIC INSTRUCTION,

THIS LITTLE BOOK

IS RESPECTFULLY DEDICATED BY

THE AUTHOR.

PREFACE.

This little book has been prepared chiefly for the use of students attending Government Science Classes and the upper class of ordinary day-schools; but it is hoped it will also be found useful for those preparing for the Oxford Middle-class Examinations, for matriculation, and as a first book for medical students and others, great care having been taken by the writer to secure the utmost degree of combined fulness and *clearness* compatible with the space at his disposal. The object of the author has, in all cases, been to communicate a sound and thorough rather than a superficially extensive knowledge of the subjects treated of, so far as the general plan and limits of the book would allow. Technical and scientific terms, having been first fully explained, are freely used, not only on account of the greater brevity and clearness which they permit, but also because of their advantage to the student himself, and of the absolute necessity of his being thoroughly *familiarized* with their use if he would pass the ordeal of the examination-room successfully.

The writer has throughout aimed to communicate *real* in contradistinction to *verbal* knowledge, and the student is fully cautioned that no real knowledge of the natural sciences is to be obtained by mere reading, and is further strongly advised to supplement his reading by careful observation and examination of the various organs and tissues of the animals daily consumed as food, also to study and familiarize himself

with the diagrams, drawing and learning them as he would a geographical map. The author also assumes that every teacher will, if possible, secure for the use of his class a set of the splendid physiological diagrams designed for popular teaching by John Marshall, F.R.S., F.R.C.S.Eng., and to be obtained through the Department of Science and Art.

The author begs to acknowledge his indebtedness to the works of Carpenter, Todd, and Bowman, Brinton, Bennett, Marshall, Huxley, Combe, Gray, Lawson, Smith, Playfair, and other gentlemen of scientific eminence.

The author, from his youth upwards, has cultivated the faith that science is God's own exposition, revealed through the researches of the human mind, of the powers and agencies by which He regulates His "providence" in this world; and that the intellectual, social, and moral progress of the race, especially of that large and important section the "working classes," can only be secured, in its high and proper degree, by the religious observance of the natural laws thus revealed to us. The writer is also fully impressed with the opinion that within one generation from the present the elements of Chemistry, Physiology, and Social Economy will form regular branches of instruction in all our ordinary day-schools, and will then be considered of even greater importance than Reading, Writing, and Arithmetic.

In conclusion the writer not only desires but hopes that this little volume may prove, at least in some small degree, an instrument by which such knowledge shall be extended.

J. ANGELL.

Manchester,
March, 1866.

NOTE.—The reader is requested to correct the following errors before proceeding to use this little work.

CORRIGENDA.

Page 2, line 5, *for* "ceases" *read* cease.
,, 13, line 1, *for* "Vegetable" *read* Vegetative.
,, 56, Fig. 8, R refers to the middle tube in the neck.
,, 80, line 19, *for* "paper, parchment" *read* paper parchment.
,, 100, Fig. 16, the round black dots representing the mouths of the *Intestinal* follicles are very imperfectly given.
,, 225, line 20, the word "the" is omitted at the end of the line.
,, 256, Fig. 51 should havc been placed in paragraph on "structure of papillæ," page 225.
,, 263, after the 20th line, "K, the knee," is omitted.
,, 270, the line of reference, Fig. 5, refers to the aperture in the bone.
,, 290, "posterior" and "lateral crico-arytenoid muscle" are very imperfectly printed in the diagram Fig. 74.
,, 292, line 18, *for* "grade" *read* grades.

THE ELEMENTS

OF

ANIMAL PHYSIOLOGY.

Natural bodies may be divided into two classes —*animate*, or organized bodies, which possess life; and *inanimate*, or unorganized bodies, or those which neither possess life nor have been derived from those which have possessed it.

Animate, or living bodies, are characterized by a peculiarity of structure termed *organization;* that is, they are made up of *organs*, and are therefore described as *organized* beings.

An organ is a part of the body which performs a *function* or duty. Thus, the brain is the organ of the mind; the eye is the organ of sight; the nose of smell; the stomach of digestion; and the lungs, liver, and kidneys are organs of excretion—that is, they perform the duty of separating poisonous or injurious substances from the blood.

The function of an organ is the *office* or *duty* which it performs. Thus, the function of the eyes is *sight;* the function of the nose is *smell;* the function of the salivary glands is the secretion or elaboration and separation of saliva from the blood; and the function of the skull is to lodge and protect the brain.

An organized structure, or an organization, consists of a combination of organs, each of which differs in structure from the rest, and performs some

function necessary to the well-being of the whole. Thus the human body consists of bones, muscles, nerves, brain; organs of digestion, circulation, respiration, secretion, excretion, &c. If either of these organs ceases to perform its functions properly, disease or death will ensue, according to the importance of the defaulting organ. If, for example, the lungs cease to perform their function, the blood will become charged with and poisoned by carbonic acid, and death will ensue. Again, if the kidneys, which *secrete* the urine, cease to perform their function, the blood will become charged with *urea*, which will poison the brain, and produce, first, insensibility, and ultimately death.

A tissue, or elementary structure, is the simplest form of organized structure that can exist. An animal or a plant may be separated into complete structures termed organs; these again may be resolved into other structures of a simple and elementary character, which cannot be further disintegrated without resolving them into the *proximate principles* of which they are composed, and thus entirely destroying them as structures.

The *tissues* preserve their distinctive characters in whatever parts of the body they are found, just as the stone, brick, iron, mortar, &c., of a building retain their general character and properties into whatever portion of the building they enter. The principal tissues are—white and yellow fibrous tissue, areolar or connective tissue, cartilaginous tissue or gristle, fibro-cartilage, osseous tissue or bone, adipose tissue or fat, muscular tissue, and nervous tissue.

Proximate Principles, or Organic Compounds.—When the tissues are disintegrated they lose all trace of structure, and are resolved into certain chemical compounds designated *proximate principles.*

These compounds are of a very peculiar and complex character, and, with one or two exceptions, cannot be produced by artificial means.

The most important proximate principles of the human body are—albumen, caseine, fibrine, syntonin, globulin, and fat. All these bodies, excepting fat, abound in nitrogen, and are therefore termed *nitrogenous* substances. Gelatin and chondrin are frequently, though erroneously, said to be constituents of the animal body. They do not, however, exist in it, but are *formed* by the action of hot water on the animal textures.

Ultimate Principles, or Chemical Elements.—When the organic compounds of which the tissues are composed are subject to *complete* decomposition, they entirely lose their organic character, and are resolved into their *ultimate elements*, which are common to the inorganic or mineral world.

About sixty simple bodies, or ultimate elements, are known to the chemist. Of these about eighteen only enter into the composition of organic beings; these are—oxygen, hydrogen, carbon, nitrogen, phosphorus, sulphur, chlorine, iodine, bromine, fluorine, silicon, potassium, sodium, calcium, magnesium, aluminium, manganese, and iron. The first two, *oxygen* and *hydrogen*, enter into the composition of all organized beings; *nitrogen* and *carbon* are also almost invariable constituents of these bodies. These four elements have therefore been termed *organogens* or essential elements. The remaining elements, of which only minute quantities, and of some of them *traces* only, enter into the composition of *organized* bodies, have been termed *incidental* elements. Iodine and bromine are only found in *marine* animals, while *traces* of fluorine are found in the teeth and bones only.

Inorganic Bodies. — Bodies that have never possessed life, nor have been derived from those possessing life, are termed *mineral* or *inorganic* bodies.

Division of Organized Bodies. — All natural bodies may thus be divided into *organic* and *inorganic* bodies. Organized beings may again be divided into *plants* and *animals*.

States of Organization. — Organized bodies may exist in three states: they may be *active*, *dormant*, or *dead*. Thus the seed of a plant may exist in the state of *activity*, or growth, as during the process of *germination;* it may exist for centuries in the *dormant* state, as in the case of seeds which, after lying 3,000 years encased with mummies in the dark stillness of the Egyptian tomb, sprang into life and grew into living corn when planted in the soil of France; or it may exist in the state of *death*, in which state, though presenting to the most minute and accurate observation all the ordinary forms and properties of organization, it is perfectly incapable, from the want of the *vital principle*, of manifesting, under any possible conditions, the phenomena of life or growth.

Life.—The vital principle is the force, agency, or influence by which *organized* beings are enabled to perform their functions, or, in other words, to live. Many, but, in the present state of our knowledge, necessarily unsuccessful attempts, have been made to define *life* as an independent principle or power, *co-existent* with but *distinct* from organization; just as all attempts to explain the forces of gravity, cohesion, chemical affinity, electricity, and magnetism, as distinct from matter, have also failed. But that organization is not life is evident from the fact that organization may exist without life. The *ultimate principles*, or chemical elements, unite, under the influence of *vital*

force, to form proximate principles; these again, under its influence, are built up into tissues; the tissues are elaborated into organs; and the organs together form the perfect animal.

Development.—All animals originate in a *germ*, or *cell*. The germ, cell, or ovum from which the higher animals, including man, originate, differs but little in form and structure from those out of which the lower animals, or even vegetables, are developed. Life would, therefore, appear not so much to depend upon as to determine organization; since all the higher forms of organization are developed from the lower. There is, first, the simple cell; this, by a process of *development*, or differentiation, divides and subdivides into other cells; these unite to form tubes, vessels, fibres, &c., which again unite and constitute organs. The extent to which this process of *differentiation*, or development, can proceed, or, in other words, the number of the organs and functions—that is, the *high* or *low* organization of the animal—therefore, seems to be dependent on the *vital principle* inherent in the original *germ-cell*. All views regarding *life* as a distinct principle are, however, *purely theoretical*. They do not aid us in our studies, and are probably rather suggested by sentimental and metaphysical considerations than by the spirit of true scientific induction.

Low Organization.—When an organized being is possessed of but few organs performing distinct functions, or is made up of a *repetition* of similar organs performing similar functions, it is said to be of *low organization*. If such animals be injured, or portions of them be cut off and removed, the life of the animal is not endangered, but the part removed will, in many cases, as in that of the *hydra*, or fresh-water

polype, develop into a complete animal. In others the lost part will be restored, as in the case of the star-fish, which may lose two or even three of its limbs, each of which will be restored to it, the life of the animal being in no wise endangered. The bodies of worms, which are made up of a considerable repetition of parts, may also be mutilated without affecting the life of the animal. In general, the smaller the number of organs the lower are the functions performed by them, and the less their importance to the general life of the animal. The amœba, shown in the following diagram, is a very interesting type of "low organization."

THE AMŒBA,

A jelly-like mass, found in fresh and stagnant water; has no mouth, stomach, or other organ; but can extend a portion of itself in any direction, and seize, surround, and digest its food. It is an animal of the lowest grade of organization.

High Organization.—When an animal, as in the case of man, is endowed with a great number of *different* organs performing *different* functions, it is said to be of *high organization.* In the bodies of the higher animals there is an absence of the repetitions found in those of the lower animals. In animals of *high* organization the relation of the various organs to

each other is of the most intimate nature, and any injury to one of the organs not only affects the function of that organ, but disturbs the harmonious action of the whole, and may even produce death. Thus any serious injury to the brain, the heart, or the lungs will produce death, even though all the other organs remain uninjured. The higher the organization of the animal, in general, the less is its power to reproduce a lost part. Also the higher the organization of an injured tissue in any animal, the less its capability of restoring the same. It is said, for instance, that if a piece of nerve be cut out it will not again be fully restored, but will be supplied by a lower form of tissue.

Vital Force.—Formerly it was the custom to refer all the actions of the living body to a peculiar power termed *vital force*, but science has shown that most of the actions that take place within the body may be explained by chemical and physical laws. At the present time it is usual to ascribe to the agency of the *vital force* those effects only that cannot be explained by ordinary *physical* and *chemical* laws; and each year's additional investigations enable us to explain more and more of the phenomena of life by ordinary physical and chemical laws.

The Physical Forces in Living Beings.—The action of the air on the blood in the process of breathing, the conversion of food into blood, the production of animal heat, the destruction of the tissues, and the daily waste which necessitates a fresh daily supply of food, are all chiefly chemical processes. Circulation is an almost purely mechanical process; the passage of the fluids through the walls of their containing vessels, veins, arteries, &c., under the influence of *exosmosis* and *endosmosis*, are all to a greater or less extent physical processes, which may be imitated

by art. Electricity also plays a part in the operations of the animal economy.

The arrangement and operation of the bones, muscles, and joints are in strict harmony with ordinary *mechanical law*. The eye and ear are constructed in relation to the ordinary laws of *optics* and *acoustics*. A knowledge of chemistry, mechanics, and natural philosophy is therefore necessary to a clear understanding of the structure and functions of the human body.

Division of Physiological Labour.—In consequence of the vast extent of the study, and of the difficulty, subtlety, and complexity of the researches it entails, physiological labour has been divided into the following branches:—Anatomy, Physiology, Pathology, and Histology.

Anatomy (from Gr., *ana*, through, and *temno*, I cut) is the science which treats of the *form* and *structure* of the various parts of the body. It is principally studied by means of the dissection of the bodies of dead animals.

Physiology (from Gr., *phusis*, nature, and *logos*, a discourse) is the science which treats of the *functions* of the various parts of the body, and the laws of health. It is principally studied by observations on the living body in a state of health, materially aided by a knowledge of the other natural sciences.

Pathology (from Gr., *pathos*, feeling, and *logos*, a discourse) is the science which treats of the *functions* of the various parts of the body in a state of *disease*. It has been described as the science of *abnormal* function. It is studied by observing the living body under all the various phases of disease.

Histology (from Gr., *histos*, a web, and *logos*, a discourse) is the science which treats of the microscopical structure and the functions of the tissues. It is prin-

cipally cultivated through the aid of the microscope. It is sometimes described under the term "general or microscopic anatomy." The immense advance made in modern physiological science is mainly owing to the progress made in this department.

Biology (from Gr., *bios*, life, and *logos*, a discourse), or the science of life, is a general term sometimes used to include all the sciences just named.

Distinctive Properties of Organized Matter.—Organized matter differs from inorganic matter in form, size, structure, chemical composition, and mode of growth, and duration. Organized bodies have usually a curved, rounded, or convex form or outline; and each species, both in animal and vegetable life, has a definite form by which it may be recognized. Inorganic matter, if of any definite form, is crystalline—that is, bounded by flat surfaces, straight lines, and angles. Organized bodies have usually a definite size, varying with the different species. Inorganic bodies, on the other hand, may be of any size, from the grain of sand to the mountain rock.

Organized bodies are *heterogeneous* in their structure, invariably consisting of an assemblage of unlike parts. If one part be detached from the rest, it presents an entirely different appearance and structure.

Inorganic bodies, on the contrary, are uniform and homogeneous in their structure; and if any one part be detached it presents the same structure and appearance as the rest; the mass, however large, consisting only of an aggregation of parts of the same kind.

Organized bodies have usually a complex chemical constitution, consisting of *ternary* or *quaternary* compounds—that is, of chemical substances containing three or four chemical elements united to form one compound. They always contain oxygen and hy-

drogen, and usually, in addition, carbon and nitrogen. Inorganic bodies have, in general, a simpler chemical composition, consisting of *binary* compounds—that is, of bodies containing two elements only, or compounds of *binary* compounds; but inorganic bodies may contain any of the 60 known elements.

Organized bodies grow or increase in size by *interstitial* deposit—that is, the increase or deposit of new matter takes place through the entire mass of the organism. Inorganic bodies, on the contrary, can only grow by external addition. The living animal takes food, which is converted into blood; this is taken to every part of the body, external and internal, where it is deposited throughout its substance as required. The mineral, however, can only grow by what adheres to its exterior.

Organized bodies go through certain *intrinsic* changes of *development*—birth, growth, and decay. They last only a certain period, which varies with the species, and is, within certain limits, altogether independent of external circumstances. Inorganic bodies will, on the other hand, if not acted upon by external agencies, last for ever.

Difference between Plants and Animals.— In their higher forms animals are easily distinguished from plants; but in their lowest they approximate so much to each other in their general characters that they are distinguished from one another with great difficulty; and even in the present state of science there are some bodies of which it is difficult to state whether they belong to the animal or to the vegetable kingdom.

Animals differ from plants in their chemical composition, shape, structure, nutrition, mode of growth, and, in their higher forms, by the possession of the powers of *voluntary motion* and *sensation*.

Animal substances are more complex in their composition, and generally contain more nitrogen, which is entirely absent in large classes of vegetable substances.

Animals are more compact in their structure than plants, and usually contain one or more *internal* cavities, or stomachs, into which food is introduced by means of an external opening, and in which cavities it undergoes more or less change to enable it to be absorbed into the body for the purpose of nutrition. Plants, on the contrary, in general, obtain their food by absorption through their *external* surfaces, and therefore do not possess or require such *internal* cavities.

Animals are nourished by *interstitial* deposit taking place through their entire mass, internal and external, thus necessitating a more or less complex circulatory apparatus ; while plants are principally nourished by deposit on their *external* surfaces, their interior undergoing comparatively little change : they therefore do not require a proper circulatory apparatus.

The *reproductive* organs of plants *fall each year;* those of animals are *permanent* during life.

Animals are endowed with the power of sensation and of voluntary motion, which, in the higher animals, form their leading features, and necessitate a *muscular* and a *nervous* system. Plants possess no such powers, and therefore require no such additions to their organisms.

Animals, viewed in relation to the air, are *reducing* agents—that is, they reduce the air, or remove its oxygen, in the process of breathing, by combining it with the carbon of their own bodies ; and expel it in the form of poisonous *carbonic acid gas*, by which the purity of the atmosphere is vitiated. Plants, on the

contrary, are chiefly *oxidizing* agents; they remove the poisonous product of animal respiration, converting the carbon into their own substance, and *liberating* the *oxygen*, thus restoring the purity of the atmosphere.

The following table, slightly extended from Galloway's "First Step in Chemistry," gives a synoptical view of the chief distinctions between plants and animals:—

A Vegetable is an Apparatus of Reduction.	An Animal is an Apparatus of Oxidation.
Is fixed.	Possesses the faculty of locomotion.
Evolves oxygen.	Absorbs oxygen.
Decomposes carbonic acid.	Produces carbonic acid.
,, water.	,, water.
,, ammonia.	,, ammonia.
Transforms inorganic matters into organic matters.	Transforms organic matters into inorganic matters.
Produces organic substances.	Consumes organic substances.
Absorbs heat and electricity.	Evolves heat and electricity.
Derives its elements from the earth and air.	Restores its elements to the earth and air.
No large internal cavities.	Large internal cavities.
Sap moves in vessels through agency of absorption, exhalation, and secretion, stimulated by heat, light, and electricity.	Blood chiefly circulates in vessels, being driven forward by contraction of vessels, or by hearts.
Root and absorbents situated externally.	Absorbents, by which nutriment is conveyed to the system, situated internally.
Grows by external deposit.	Grows by interstitial deposit.
Possesses no proper sensibility.	Possesses sensibility, and, in the higher classes, consciousness.
Reproductive organs fall every year.	Reproductive organs are permanent.

Organic or Vegetable Functions.—Many of the functions performed by living bodies are *common* to both plants and animals, being equally necessary to the existence of both; they are therefore termed the functions of organic life. They are digestion, absorption, circulation, respiration, nutrition, secretion, excretion, and reproduction.

Digestion (from L., *dis*, asunder, and *gestus*, carried) is the process by which the *nutritious* parts of the food are converted into blood.

Absorption is the process by which liquids are absorbed into the system by means of veins, and a peculiar system of vessels termed *absorbents*.

Circulation (from L., *circulus*, a circle) is the process by which the blood is carried out from and returned to the heart, from the various parts of the body.

Respiration (from L., *re*, again, and *spiro*, I breathe) is the process by which the blood is *purified*, and carbonic acid *excreted*, by the contact of the oxygen of the atmosphere. The principal organs of respiration are the lungs.

Nutrition (from L., *nutrio*, I nourish) is the process by which the various tissues of the body are *built* up, and repaired out of the constituents of the blood.

Secretion (from L., *secerno*, I separate) is the process by which fluids, and other substances necessary to the proper performance of the functions of the body, are separated or elaborated from the blood by means of *glands* or other organs. Thus the *saliva*, or spittle, is elaborated from the blood by the *salivary glands*, and is necessary to perfect digestion.

Excretion (from L., *ex*, out, and *cerno*, I sift) is the process by which the waste products of the tissues, and other injurious substances, are separated from the

blood, and thrown out of the body by means of glands or other organs. Thus the urine is a poisonous substance *excreted* from the blood by the kidneys. In the disease termed *ischuria* the kidneys are unable to perform their functions, and the blood becomes charged with and poisoned by *urea*, which rapidly produces insensibility and death.

Reproduction is the process by which life is perpetuated and the species is propagated.

Animal Functions.—In addition to the functions just enumerated as common to plants and animals, animals are characterized by the performance of certain functions which are not necessary to their mere existence as *living* beings, but by which they are brought into more intimate relation with each other, and with the surrounding world. These functions are termed the *functions of relation*, or animal functions ; they are *spontaneous motion*, *sensation*, *thought*, and *speech*. The two latter functions are characteristic of the higher animals only.

Spontaneous Motion.—The power of spontaneous motion is common to all animals. All excepting the lowest classes of animals possess the power of *locomotion*, by which they are enabled to seek their food. Man is enabled, by the exercise of this power, to bring himself into relation with any department of nature, and with the rest of the human family, for the purpose of cultivating his mind and availing himself of the forces which nature has placed at his disposal. Without this power the highest of all organs, the human brain, would be comparatively useless.

Sensation (from L., *sentio*, to perceive) is the process by which we become conscious of internal or external impressions through the agency of the brain and nerves.

Thought.—The power of thought, including under this term the various powers of the mind, as consciousness, volition, the affections, and the intellect, is, in this life, dependent on the healthy action of the brain.

Chemistry of the Organogens.—Organic bodies are chiefly composed of oxygen and hydrogen, with which are generally combined carbon and nitrogen. Hence these bodies have been termed *organogens.* As life and all the animal and organic processes, more especially including those of nutrition and respiration, are dependent on the chemical changes that are perpetually taking place among these constituents of the animal frame, a knowledge of their properties is absolutely necessary to a clear understanding of these processes.

Prepare three jars of oxygen gas, by heating a mixture of chlorate of potash and the black oxide of manganese, in a retort, or Florence flask, fitted with a bent tube, placed under water in a basin or vessel containing a perforated shelf (as explained in Buckmaster's "Chemistry"). Place the bottle neck downwards, having previously filled it with water, to expel the air. Apply heat to the retort, and, after the air has been expelled, collect the oxygen gas which comes over, by displacing the water.

Properties of Oxygen Gas.—Observe that it is transparent, colourless, inodorous, and tasteless, and that in all its purely physical properties it closely resembles atmospheric air. Perform the experiments described below, and you will observe it possesses the following special or characteristic properties:—it is uninflammable, is a powerful supporter of life and combustion, and it has the power of entering into *chemical union* with most other chemical elements.

Experiment I.—Plunge a red-hot but not inflamed taper or wooden match into a jar of oxygen ; the gas will not take fire, but the match or taper will immediately burst into a flame. The flame may be blown out, and the match rekindled by again plunging it into the oxygen. This action may be repeated several times in succession with the same bottle of gas. This proves that oxygen is uninflammable, and that it is a powerful supporter of combustion. The candle and the wood consist chiefly of carbon and hydrogen ; the oxygen combines with the hydrogen and produces *water*, and with the carbon and produces *carbonic acid gas*. The products of combustion are, therefore, watery vapour and carbonic acid. A similar action is continually proceeding in the human body, which, in consequence of its very low intensity, is designated *slow* combustion.

Experiment II.—Into the second jar of oxygen plunge a piece of red-hot charcoal ; it will immediately become white-hot, emitting a most intense heat, and will gradually disappear in the form of invisible gas, leaving a small residue of white ash only. In this case the carbon (charcoal) combines with the oxygen, producing carbonic acid, which is a heavy, poisonous gas.

Experiment III.—Into the third bottle of oxygen plunge a small piece of burning phosphorus ; its flame will immediately become of dazzling intensity, so that the eye can scarcely tolerate its light ; and dense white fumes, similar to those formed when a lucifer match is kindled, will be produced. In this case the oxygen combines chemically with the phosphorus, and produces a compound termed phosphoric acid.

Prepare some *hydrogen* gas in the following manner: —Procure a glass flask ; attach a glass tube drawn out

to a jet to it, by means of an airtight-fitting cork ; into the flask pour some water, sulphuric acid, and zinc clippings ; replace the cork and tube ; allow the first portions of the gas to escape, as in the preparation of oxygen ; and then apply a light to it. It will unite with the oxygen of the atmosphere, burning with a very pale flame, but giving out a most intense heat. Hold a cold glass tumbler over the jet of burning gas; it will immediately become dimmed with condensed aqueous vapour. The product of the combustion of hydrogen is, therefore, watery vapour. Hydrogen gas is the lightest substance known. It resembles oxygen and the air in its ordinary physical qualities, but is very inflammable, and will not support combustion or animal life.

Oxidation.—In each of the experiments just described the carbon, hydrogen, and phosphorus combined chemically with the oxygen—that is, underwent *oxidation*, producing respectively carbonic acid, water, and phosphoric acid. The carbon, hydrogen, phosphorus, and sulphur of the tissues in the animal system undergo a similar process of oxidation, animal heat being generated, and carbonic acid, water, phosphoric and sulphuric acids being evolved as *waste* products ; the amount of the waste products greatly increasing during, and for a short time after, severe mental or muscular labour.

Carbon. — Procure a piece of iron gas tubing about six inches long ; fill the interior with chips of wood ; close the ends with clay, leaving a small aperture at one end for the escape of the gases evolved during the decomposition of the wood. Place the whole in the interior of a bright red fire, and heat to redness for half an hour ; then remove it from the fire and allow it to cool. After it has thoroughly cooled

remove the clay stoppings, and empty the tube; it will be found no longer to contain wood, but a light, porous, brittle, black substance, weighing much less than the wood originally introduced, and differing entirely from it in its properties. This black substance, the residue of the process, is *carbon*, the chemical basis of the vegetable kingdom; its popular name is *charcoal.* It once formed, in combination with oxygen, as *carbonic acid*, a gaseous constituent of the atmosphere; the plant, under the peculiar agency of its *vital force*, called into play by the stimulus of sunlight, extracted it from its gassy ocean and fixed it solidly in the substance of its own being. Coal, the great source of artificial heat, which is of vegetable origin, has, in accordance with this view, been beautifully described as the stored-up or frozen sunlight of the past. In the experiment just described for the preparation of carbon, the wood *is not burnt*, as is popularly supposed, but *decomposed*—that is, separated into its constituents. The entire object of the experiment is to prevent the contact of the oxygen of the atmosphere, without which the wood cannot burn; and any arrangement by which wood, or any other similar vegetable or animal substance, is exposed to a red heat, causes that substance to *decompose* and yield up more or less of its carbon.

The physical qualities of carbon vary very greatly according to its source. Carbon forms alike the substance of common *soot*, and of the *diamond*, the most prized and beautiful of our gems.

Chemical Properties of Carbon and Carbonic Acid.—The chief chemical quality of carbon is its affinity or attraction for oxygen, with which it does not ordinarily combine below a red heat, but with which it combines in the animal system

with great facility at the ordinary temperature of the body.

When carbon and oxygen combine at a high temperature, there being a greatly insufficient supply of oxygen, a substance termed *carbonic oxide* is produced. This compound, which is a poisonous gas, however. is comparatively uninteresting to the physiologist, since it is not formed in the animal system.

When carbon and oxygen combine at any temperature, in or out of the animal system, there being a sufficient supply of oxygen, *carbonic acid gas* is produced. It is a compound of one atom of carbon chemically combined with two atoms of oxygen (CO_2). It is a transparent, colourless, invisible, irrespirable, poisonous gas, and is much heavier than atmospheric air, thereby tending, at first, to collect in fissures of the earth, wells, caves, and cellars. The air expired from the lungs contains about 4·3 per cent. of this poisonous gas. When first expired it is warmer, and therefore *lighter*, than the surrounding atmosphere; in consequence of which it rises above our heads, leaving the purer unrespired air to flow to the level of our mouths, by which we continue to breathe, if the room be properly ventilated, pure atmospheric air. Pure undiluted carbonic acid is very heavy, and may be poured, like water, from one vessel into another, and if it be breathed, it will produce immediate death by suffocation; but if it be very largely diluted with air it may be breathed unconsciously, producing, however, great *vital* depression, and consequently rendering us liable to almost every kind of disease.

Nitrogen is to the animal what carbon is to the vegetable; it has, therefore, been described as the *basis* of animal substances. It may be easily prepared by burning a piece of phosphorus on a deflagrating

stool (a little cup on a stand which raises it several inches out of the water) in an inverted jar of air, its neck being under water. The phosphorus burns by combining with the oxygen of the enclosed air; this, however, being speedily consumed, the burning phosphorus is soon extinguished; the water gradually rises about one-fourth or one-fifth the height of the jar; the white fumes that have been generated gradually fall, and an invisible gas, *nitrogen*, is left.

Examine the *nitrogen* thus prepared, and you will find it is a transparent, colourless, invisible, inodorous, tasteless gas. Plunge a burning candle into it, and you will find that not only will the gas not burn, but it will also extinguish the flame of the candle, and if a living mouse be placed in the jar it will die. *Nitrogen*, therefore, is uninflammable, and a non-supporter of life and combustion, and is, in fact, remarkable for its *negative* qualities. But, singular as it may seem, nitrogen, which in its free state is so devoid of all activity, is an essential constituent of the most poisonous, the most powerfully explosive, and the *highest* organic compounds. Its principal use in the atmosphere, of which it forms four-fifths, is to dilute the oxygen.

It is desirable the reader should perform these experiments himself, or, at least, induce his teacher to do so before his class. No really clear or accurate knowledge of physiology is possible without a knowledge of at least so much of the chemistry of the *organogens* as is here given. For further information the reader is referred to Buckmaster's "Chemistry," and is recommended to join one of the numerous Government Science Classes, where chemistry, physiology, and other natural sciences are so efficiently and cheaply taught.

The limited space at our disposal in this little book will prevent our more than simply glancing at the remaining chemical elements, which have been termed *ultimate elements of the second order*, and *incidental elements.*

Phosphorus is a solid, soft, semi-transparent, pale yellowish, elementary substance, which glows in the dark, from which circumstance it derives its name. It has a very powerful attraction for oxygen, and is so exceedingly inflammable that it often takes fire spontaneously, and must therefore be kept under water. It is a constituent of bone, brain, and nerve. It is prepared commercially from burnt bones.

Sulphur is an opaque, greenish yellow, brittle, tasteless, insoluble, but very inflammable substance ; it is a constituent of albumen, fibrin, casein, and globulin. The offensive odour of rotten eggs and putrifying animal matter is due to the sulphur they contain.

Chlorine is never found free in nature. It is a yellowish green, irritating, suffocating gas. It exists in the animal system in combination with the metal sodium as common salt, which forms a constituent of the blood and the tissues, and in combination with hydrogen, forming muriatic or hydrochloric acid, one of the principal constituents of the *gastric juice*, so necessary to digestion.

Bromine and **Iodine** are very similar to chlorine in their general chemical characters, and are found in marine animals only.

Fluorine has never yet been obtained in a *free* and separate state. Its properties have not, therefore, been described. The human body contains about two ounces of fluorine in combination with the metal calcium, forming the fluoride of calcium.

Silicon, the basis of flint, is found in very minute quantities in the bones, teeth, hair, and urine.

Potassium, Sodium, and **Aluminium** are metals of which small quantities, and of the last-named traces only, are found in the animal system. They exist principally in combination with oxygen.

Magnesium is the metallic base of magnesia, which is found in combination with phosphoric acid, as phosphate of magnesia, in the bones.

Calcium is the most abundant metal in the human body, which contains about two pounds of this metal. It exists principally in combination with oxygen and phosphoric acid, forming phosphate of lime, or *bone earth*.

Iron is principally found in *hæmatin*, or *hæmatosin*, the true colouring principle of the blood.

Manganese is a metal which very closely resembles iron in its chemical qualities. It is said to be found in the hair.

In the Food Collection of the South Kensington Museum a most interesting case of organic bodies has been prepared, which at once exhibits to the eye of the observer the quantity and weight of each substance entering into the composition of a human body weighing 11 stones, or 154 lbs. The following tables, indicating the respective quantities of the *ultimate elements* and of the *proximate principles* entering into the composition of a human body of the weight specified, are taken from the "Guide to the Food Collection" of that Museum, prepared by Dr. Lankester :—

TABLE OF THE ULTIMATE ELEMENTS OF THE HUMAN BODY.

	lbs.	oz.	grs.
Oxygen	111	0	0
Hydrogen	14	0	0
Carbon	21	0	0
Nitrogen	3	8	0
Phosphorus	1	12	190
Calcium	2	0	0
Sulphur	0	2	219
Fluorine	0	2	0
Chlorine	0	2	47
Sodium	0	2	116
Potassium	0	0	290
Iron	0	0	100
Magnesium	0	0	12
Silicon	0	0	2
	154	0	0

TABLE OF PROXIMATE PRINCIPLES OF THE HUMAN BODY.

	lbs.	oz.	grs.
Water	111	0	0
Gelatine	15	6	0
Fat	12	0	0
Phosphate of lime	5	13	0
Carbonate of lime	1	0	0
Albumen	4	3	0
Fibrin	4	4	0
Fluoride of calcium	0	3	0
Chloride of sodium	0	3	376
Sulphate of soda	0	1	170
Carbonate of soda	0	1	72
Phosphate of soda	0	0	400
Sulphate of potash	0	0	400
Peroxide of iron	0	0	150
Phosphate of magnesia	0	0	75
Phosphate of potash	0	0	100
Silica	0	0	3
	154	0	0

Azotized Proximate Principles.—The following azotized organic principles require a brief notice:—Protein, albumen, fibrin, syntonin, casein, globulin, hæmatosin, gelatin, and chondrin.

Protein (from Gr., *proteuo*, I hold the first place) is the name given to a substance discovered by Mulder, which he supposed to be the essential constituent of three important nitrogenous principles—albumen, fibrin, and casein. He supposed these bodies to be compounds of protein with different proportions of sulphur and phosphorus. This theory is,

however, now generally discarded, though the term is still much used. The following is the formula of the protein according to Mulder :—(C_{36} H_{27} N_4 O_{12}).

Albumen (from L., *albus*, white) is the characteristic ingredient of white of egg, and of the serum of blood; the former is sometimes designated *ovalbumen*, the latter *seralbumen*. When perfectly pure, and free from salts and alkali, it is probably insoluble. In its ordinary state, as in white of egg, it coagulates when heated to 150° or 160° Fahrenheit, forming a white, opaque, soft, solid, insoluble substance. Acids, many salts, especially those of copper and mercury, coagulate it. It is one of the best antidotes in cases of poisoning with salts of mercury. The offensive odour arising from rotten eggs is due to the sulphur they contain. It forms highly nutritious *plastic* food.

Fibrin is a nitrogenous compound which very closely resembles albumen in its chemical properties and composition. It differs from albumen principally in its power of *spontaneous coagulation*. Fibrin derives its name from its property of *spontaneously* separating from newly-drawn blood, in the form of a network of *fibres*, in which it entangles the red corpuscles of the blood; the whole forming the well-known *clot*, or *coagulum*, of the blood.

Syntonin (from Gr., *suntonos*, stretched) is the term applied to coagulated or solid fibrin. It is the principal constituent of *muscular fibre*.

Globulin is the albuminous constituent of the red corpuscles of the blood; it closely resembles ordinary albumen. It occurs mixed with albumen in the crystalline lens of the eye, and is therefore also termed *crystallin*.

Casein (from L., *caseus*, cheese) is the character-

istic and most valuable constituent of milk. It is held in solution by the slight excess of free alkali (soda) which fresh milk always contains. When acid is added to milk, or when it turns sour by the formation of *lactic* acid, the free alkali (soda) is neutralized, and the *casein* separates in the form of large white flakes, popularly termed the *curd*. Casein, curd, or cheese, when digestible, is one of the most nutritious substances known.

Hæmatin, or **Hæmatosin,** is the true colouring principle of the blood. It is a soluble, coagulable, albuminous substance, which contains more iron than any other constituent of the body. According to Mulder it contains 6·6 per cent. of metallic iron. It is said that a French *savant* constructed an iron mourning ring from the iron obtained from the ashes of a departed friend.

Gelatin, though sometimes described as one of the proximate principles of the animal body, really does not exist in the tissues, but is developed by the prolonged action of boiling water upon certain animal textures. *Isinglass* is nearly pure *gelatin*. *Glue* and *size* are inferior qualities of gelatin. Fibro-cartilage, white fibrous tissue, the skin, bones, &c., yield gelatin on continued boiling, especially under high pressure. Gelatin is very soluble in hot water. A hot aqueous solution containing 1 per. cent. of gelatin will *gelatinize*, or solidify into the form of a jelly, on cooling. It is precipitated by tannin and several metallic salts.

Chondrin, in general, resembles gelatin, though it differs slightly from it in chemical composition. The vegetable acids, alum, and the acetates of lead, coagulate solutions of *chondrin*, but do not act upon *gelatin*. Chondrin is obtained by the action of hot water on the *cartilage* of the ribs, joints, trachea, nose, ears, &c.

The tissues, microscopic structures, &c., will be described towards the end of the volume, when the reader will have acquired greater interest in, and be better able to appreciate the importance of, that branch of physiological study.

The non-azotized proximate organic elements are chiefly starch, sugar, gum, lignin, and the fats. They all consist of carbon, oxygen, and hydrogen.

Starch is entirely of vegetable origin. There is no satisfactory evidence that it enters into the composition of animal bodies. It is insoluble in cold water. In the animal body it is first converted into sugar, then dissolved, and absorbed into the blood, and either burnt as respiratory or fuel food, or converted into fat. It has the following composition:— $C_{12}\,H_{10}\,O_{10}$.

Sugars are also essentially a vegetable product. Their general properties are well known. They have a sweet taste, are soluble in water, and more or less crystallizable. They yield carbonic acid and water on fermentation. They constitute respiratory or fuel food, by which the animal heat is sustained, and are convertible into fats by the action of the animal organism. Common crystallizable cane sugar has the following formula:—$C_{12}\,H_{11}\,O_{11}$. Grape sugar,—$C_{12}\,H_{11}\,O_{11} + 3\,HO$. Much of the sugar taken into the body is changed into *lactic acid.*

Gum is a vegetable product resembling starch and sugar in its general chemical characters; its formula is $C_{12}\,H_{11}\,O_{11}$. It is soluble in water, forming the well-known mucilaginous solution. It is probably converted into sugar in the animal body.

Fats are compounds of carbon, hydrogen, and a much smaller proportional quantity of oxygen than is contained in sugar, starch, &c.; they are, therefore,

greatly superior as *fuel* foods. They are exceedingly combustible, and have very nearly the following composition :—$C_{10} H_9 O$. Their peculiar greasy appearance and feel is well known. Fats are usually complex substances, containing certain organic principles — margarine, stearin, and olein, which it is unnecessary here to describe.

WASTE—THE LIVING BODY CONSIDERED AS A MACHINE.

All substances, even the hardest, when in action, or in contact with moving bodies, lose a portion of their material, and undergo a process of wear or *waste.*

The mountain tops are gradually lowered ; the hardest rock is certainly though slowly reduced ; our ships, our houses, our machinery, our tools, our clothes, and all implements of domestic use, gradually yield to the destructive agency of this process of wear or *waste.* The late Professor Cowper used to show his classes a carpenter's plane, in the body of which had been worn, by the continued friction of the hand, a cavity nearly large enough to contain a man's fist. He had given a new plane in exchange for the old one, in order that he might exhibit it to his classes as an illustration of *waste* produced by mechanical action. Soft solids, especially those containing liquids, waste more readily than hard ones.

The living body is chiefly made up of soft solids and liquids ; it is always in a state of greater or less mechanical activity, and is the seat of continuous and varied chemical action. When powerful mechanical, chemical, and vital activities are combined this process of waste is greatly increased, and it is supposed that

the entire substance of the body is changed in the course of two or three years; and it has been further calculated that a quantity of material equal to the entire weight of the body is carried away every forty days, so that the greater part of our body is renewed in that time.

Starvation proves Waste.—If food be entirely withheld from an adult he gradually loses weight, becoming thinner, lighter, and feebler each day, until he has lost about 40 per cent., or two-fifths of his entire weight, when death usually takes place. Death generally occurs in from ten to twenty days, and is very rarely delayed beyond fourteen days. In one or two cases, however, it has not occurred till the twenty-third day after deprivation from food. If an average adult human being be *partially* but quite insufficiently fed, he will, as before described, lose bulk, weight, &c., but in this instance much more slowly than when the deprivation from food is entire. When the bodily loss has amounted to about 40 per cent. death will ensue, as in the previous case. The period of death from starvation, except in certain cases of disease, as in fevers, &c., depends upon the rapidity with which waste exceeds nutrition, until the limit of loss consistent with life (about 40 per cent.) is reached, when death leaves the body a prey to the common processes of decay and putrefaction.

Rate of Waste.—Various attempts have been made to ascertain the rate of waste in the human body by calculations founded on the amount of the daily *egesta*, or substances thrown out of the body. The daily *egesta* consist chiefly of *carbonic acid gas*, about 2 lbs.; *water*, about 6 lbs.; *urea*, about 480 grs.; *salts*, 485 grs.; in addition to the fæces, which consist chiefly of the undigested residue of the food.

These *egesta* are partly derived from the disintegra-

tion and oxidation or combustion of the waste tissues, and partly from the oxidation of the *food*. It has been calculated that about 1½ lb. of the carbonic acid gas, about ⅗ lb. of the water, and about 240 grs. of the urea are derived from the disintegration and combustion of the tissues of the body itself, more especially of the muscular and fatty tissues, the rest being derived from the food, including drink, daily ingested.

The following table, from Brinton, indicates more elaborately the estimated amount of daily bodily waste according to the researches of Valentine and others. The *typical* man, on whom the calculations are supposed to be based, represents a healthy male, 35 years old, 5 ft. 6 in. in height, and 10 stones in weight. It must, however, be understood that the quantities given are simply approximative, and must vary with constitution, temperature, mental and bodily activity, state of health, and the general condition of the atmosphere :—

TABLE OF DAILY BODILY HUMAN WASTE.

		grs.
Carbonic acid		14,000
Water (8,400 of which are formed by combustion)		42,000
Urea (including carbonate of ammonia, 20 grs. ?)		480
Other organic constituents of the urine ; namely, uric acid (8), kreatinin (7), kreatine (4½), lactic and hippuric acids (indeterminate), together, about		20
Salts { by the skin	80	
,, fæces	50	830
,, urine	700	
Total		57,330

The carbonic acid and water of the 57,330 grs. of daily matter *egested* are partially made up of the 14,570 grs. of oxygen, daily absorbed by the lungs and skin in the process of respiration. If we deduct from the 57,330

grs. of *egesta* the 14,570 grs. of absorbed oxygen, the remainder, 42,760 grs. (about 6 lbs.), will show the quantity of food daily required to support the system.

Annual Change of Bodily Substance.—During the course of one year the bödy consumes about twenty times its own weight of food and oxygen. It receives about 800 lbs. of solid food, about 1,500 lbs. of liquids, and about 800 lbs of oxygen, which is principally absorbed through the lungs in the process of breathing. The total weight of substances consumed by the body during one year, therefore, amounts to upwards of 3,000 lbs., or about a ton and a half. If we multiply this quantity by the number of human beings in the world, some idea will be obtained of the important part man plays in the mere physical economy of the universe.

The living organism wastes because of the mechanical, chemical, and vital actions to which it is subject.

The *mechanical* actions are produced through the agency of the voluntary and involuntary muscles, the bones, and the ligaments. Every time we move our arm, or even wink our eye, a portion of the muscle is destroyed, and requires to be repaired or restored by the process of nutrition. All mental action is performed through the agency of the brain and nervous system, and every time we think a thought, see an object, or hear a sound, a portion of the brain and nerve of sight or of hearing is destroyed, and ceases to exist as brain or nerve. No animal can continue to exist if its body falls below a certain temperature. A process of slow combustion, or burning, is continually progressing in its substance, by which the animal heat is sustained and the bodily weight is diminished.

The bones, joints, ligaments, and skin are all subject

to wear because of the mechanical attrition which they undergo, and therefore require repair. The liquids of the body also suffer loss by evaporation, transpiration, &c.

Continual loss is also sustained in the various processes of solution, circulation, and the chemical changes incurred in the processes of digestion, secretion, &c.

Waste is proportioned to Exertion.—Increase of bodily or mental exertion produces increased waste. The bricklayer's labourer or the navvie renews his muscular, osseous, and fatty tissues much more rapidly than the student, and, as a consequence, enjoys a better appetite, possesses a more vigorous digestion, and consumes a much greater quantity of food. During his pedestrian summer tour the quantities of carbonic acid, water, urea, and salts eliminated from the body of the student, professional man, or clerk, are very greatly increased, sometimes even doubled; the quantity of food ingested being correspondingly increased. In this way are developed that increase of appetite and vigour, and that consciousness of high health, which go far to counteract the debilitating tendency of all sedentary employments. Again, the brain and nervous system of the student, being much more active than those of the navvie, suffer a much more rapid process of disintegration and repair, and are more frequently and entirely renewed than those of the navvie. In cases of excessive mental labour or study, also in certain cases of mania and insanity, it has been observed that the quantity of salts, especially the phosphates, eliminated in the urine, is very greatly increased. The phosphorus in the phosphates is, in this case, derived from the destruction of the brain and nervous tissues; the great increase of the phosphates proving the greatly increased rate of

disintegration of brain and nerve consequent on the excessive brain labour.

The Living Body considered as a Machine.—The living body has been compared to a machine performing a certain amount of work, the work being greater the greater the amount of coal or other fuel consumed. In the economy of the living body the expenditure of force is directly proportioned to the oxidation, combustion, or metamorphosis of the food and tissues. This principle is very adequately expressed in the alliterative, "*Food is force.*"

In the working of the steam engine the real agent is the heat. The boiler, cylinder, piston, crank, and wheels may all be complete,—nay, there may be coals and water,—but the machine is motionless; there is no dynamic or moving force. The amount of work done is directly proportioned to the heat developed and applied; but the heat developed depends on the metamorphosis the coal undergoes in the process of combustion, or, in other words, on the quantity of coal burnt. It is easy to calculate the *mechanical power* of the steam engine by the quantity of the heat evolved and applied; and it is very easy to calculate the quantity and intensity of the heat evolved by determining the quantity of fuel of a given chemical composition consumed in a given time. Dr. Joule, of Manchester, has determined, after many years of able and laborious experiment, that the quantity of heat which will raise the temperature of one pound of water one degree, measured on the centigrade thermometer, will, if applied mechanically, raise 1,392 lbs. avoirdupois one foot high.

This quantity of heat has therefore been taken as the *mechanical unit of heat*, and by means of it we are enabled to determine the *mechanical equivalent*, or

moving power of any degree of heat. It has been determined by experiment that during combustion 1 lb. of carbon evolves as much heat as would raise 8,000 lbs. of water one degree in temperature. 8,000 × 1,392 = 11,136,000 lbs., or the number of pounds avoirdupois that may be raised through 1 foot of space by the mechanical force evolved in the combustion of 1 lb. of carbon. Again, it has been determined that the heat evolved during the combustion of 1 lb. of hydrogen—that is, by its chemical union with the necessary quantity of oxygen, transmuted into *mechanical force*, would raise the astounding weight of 47,328,000 lbs. one foot high. But the union of the oxygen and the carbon, and the oxygen and the hydrogen, in the human body is attended by the evolution of the same quantity of heat as in the case of its ordinary combustion outside the body; therefore, it is easy to calculate approximatively the *mechanical equivalent* to the forces set free in the body in the performance of the mechanical, chemical, and vital processes, if we can only determine the respective quantities of carbon, hydrogen, &c., consumed or oxidized in the system.

According to Liebig an ordinary man consumes, or converts into carbonic acid, about $13\frac{9}{10}$ oz. of carbon per day. This is probably a little in excess of the true amount. Adopting this estimate, the amount of force generated *daily* in the human body by the combustion of the carbon alone would, if used mechanically, raise 9,674,400 lbs. avoirdupois one foot high.

Vital Decomposition.—The body, as has been shown, is the seat of constant change. Its particles are continually undergoing a series of changes, of decomposition and degradation,—are incessantly dying and being removed from the system. But the dead particles are as incessantly being replaced by newly-

formed living ones, so that the body still retains its general life, form, and properties. Further, the higher tissues are only partially degraded, suffer only an incipient decomposition; complete or final putrefactive decomposition being, in general, arrested until after their expulsion from the animal system. The waste products of the higher tissues (the nitrogenous) are eliminated in a somewhat complex form, as in *urea* ($C_2 H_4 N_2 O_2$) and other compounds, which, after their expulsion from the body, are resolved, by ordinary putrefactive decomposition, into water, carbonic acid, and ammonia.

Putrefactive Decomposition is that form of decomposition which most dead organic matter undergoes when exposed to the combined influences of warmth, air, and water. It rapidly extends through the entire mass of the substance, which, in general, assumes a state of fermentation. It is entirely produced by chemical affinity unresisted by *vital force*, and consists in a downward or degrading action, by which the complex *ternary* and *quaternary* organic compounds are gradually reduced to the simplest *binary* combinations, consisting chiefly of water (HO), carbonic acid (CO_2), and ammonia (NH_3). These escape into the atmosphere, again at some future period to be drawn into the cycle of organic change through the agency of plant life.

Organic Products of Vital Decomposition.—The chief organic product of vital decomposition is *urea* ($C_2 H_4 N_2 O_2$), which very greatly exceeds all the others in quantity and importance. The remaining principles are—certain constituents of bile, kreatine, kreatinine, uric and hippuric acids, &c. These bodies will be explained when describing the liver, kidneys, &c., by which they are excreted.

General Functional View of Man.—Man is endowed by his Creator with the power of performing numerous more or less complex functions. His highest, noblest, and most distinctive function is *thought*, including under this term knowledge, reflection, the religious and moral feelings and emotions, the sentiments and affections. The mind would be unable to act unless brought into relation with the external world through the function of *sensation*, including sight, smell, hearing, taste, and touch. Unable to perform these functions, wanting in the powers of sensation, his position in this world would be a blank ; all would be darkness and chaos. Wanting these windows of the soul, all would be cold, vacant, and cheerless. Sightless, deaf and dumb, unconscious of all external existence, no light, no colour, no sound, no beauty, no friendship to act on the imprisoned soul, the mind would be a mere blank. But given a mind with all its glorious powers, and the faculties of *sensation*, without which the mind would be useless, it is still necessary that man should possess the power of bringing himself into contact with new scenes, new agencies, new friends, by which the mind is filled with an ever-flowing current of new thoughts, ideas, and aspirations, and by which he is enabled to collect the material substances essential to the support of his existence,—therefore are added to his endowments the powers of *motion* and *locomotion*. But the functions of thought, sensation, and locomotion imply material organs and actions, with their inseparable accompaniments of *waste* and *disintegration*. These necessitate other ministering functions, including digestion, circulation, respiration, and nutrition, by which the material organs of the higher functions are kept in a state of continued *renovation* and *repair*. And still other functions are superadded, including

those of *secretion* and *excretion*, by which the effete and worn-out materials of the system are carried away, and health and purity maintained.

General Structural View of Man.—If you were to imagine a human body to be gradually dissected or taken to pieces, beginning from the exterior, the various structures would reveal themselves in the following order :—On the outside, the *skin;* under it a general layer of *fat*, more or less perfect; upon removing the skin and fat a large number of bundles of red flesh (the *muscles*), which pull the bones and move the body, would be seen. Under these lie the bones, to which the muscles are attached by whitish cords (the *tendons*). We should then come to the great cavity of the trunk, including those of the chest and abdomen. The upper part of this cavity is enclosed by the ribs, its lower being enclosed by soft walls only. This cavity contains the blood-making organs (the organs of digestion), the blood-purifying organs (the lungs), a force-pump (the heart), a system of blood-pipes for distributing the building and repairing material through the body, and a system of sewerage (the liver, kidneys, intestines, &c.), by which the purity of the commonwealth is maintained.

Behind the *great* cavity, and enclosed within the bones of the spine and skull, is another, a smaller cavity, in which is situated the great telegraphic apparatus (brain and nerves), which sends out silver strings (nerves) to all parts of the body, and guides and directs the machinery of the whole. To the trunk, or main system, are appended four extremities or limbs, two upper and two lower, which are also intimately connected with the central telegraph apparatus, by means of its silver strings, and with the blood-making

and blood-distributing system, by means of branches of the blood-pipes previously referred to.

The following table will aid the reader in forming a clearer view of the animal organs and functions :—

TABLE OF ORGANS AND FUNCTIONS OF MAN.

	Functions.	*Organs.*
Functions of Relation . .	Thought and Sensation . .	Brain. Nerves.
	Voice . . .	Larynx. Vocal cords.
	Motion and Locomotion . .	Nerves. Muscles. Tendons. Bones. Ligaments.
Vegetative or Organic Functions	Renovation and Repair . .	Stomach and organs of digestion. Heart, or organs of circulation. Capillaries, or organs of nutrition. Lungs, or organs of respiration.
	Removing the Waste . .	Absorbents, or lymphatics. Organs of respiration. Organs of secretion. Organs of excretion.
	Organs of Reproduction.	

DIGESTION AND ORGANS OF DIGESTION.

General View of Digestion.—In the process of *digestion*, or blood-making, the food is first broken or crushed, as in a mill, the teeth acting as the cutters or grinders. It is then passed into a cavity, the stomach, where the nutritive material is gradually dissolved out by the agency of certain fluids, aided by warmth and agitation. The stomach may, in this respect, be regarded as a sort of "chemical digester," or solution bottle. The nutritive solution is absorbed into the blood almost as rapidly as it is formed. The remaining portions, consisting principally of the insoluble and useless parts of the food, are then slowly squeezed and pushed along the intestinal tube, until they are driven out of the body as effete and injurious material. They are, however, at first mixed with more or less undissolved nutriment, which has escaped solution in the earlier stages of the process. This is gradually dissolved by the aid of other juices which it meets on its journey through the system, and is also absorbed and mixed with the blood.

The liver, pancreas, and other organs aid digestion by supplying the necessary solvent juices.

Digestion is the process by which the *nutritious* parts of the food are converted into blood, and the *innutritious*, or non-blood-forming parts, are expelled from the body. It comprises eight sub-processes —prehension, mastication, insalivation, deglutition, chymification, chylification, absorption, and defæcation.

Prehension, or the taking of food into the mouth, is chiefly performed by the hand, aided by the lips,

front teeth, tongue, and cheeks. The lips are moved by about twenty muscles, by which they are enabled to grasp and retain the food. At their margin the skin becomes continuous with the *mucous membrane* lining the digestive cavity.

Mastication is the process by which the food is crushed and broken up into small particles. Its object is to overcome the force of cohesion, by which the particles of the food are held together, and resist digestion, and to enable the juices necessary for their solution to permeate them readily.

The organs concerned in *mastication* are the mouth, teeth, tongue, cheeks, palate, the upper and lower maxillary bones, and certain muscles termed the muscles of mastication.

This process is effected in the mouth, which contains the principal organs of mastication. In order to perform their cutting and bruising operations more effectively the teeth and jaws receive a threefold motion—a *vertical* movement, by which the food is cut and bruised; an *antero-posterior*, or backward and forward movement; and a *lateral* movement, by which the food is more thoroughly triturated. The *tongue* is an important auxiliary to mastication, continually collecting the food together, and bringing fresh portions under the teeth. The cheeks and palate also help by retaining the food in the mouth. The jaws are put into motion by the *muscles of mastication*.

The Mouth is an irregularly shaped cavity, bounded in front by the lips, behind by the *fauces*, above by the hard and soft palates, which separate it from the cavity of the nose, and below by the tongue. (Fig. 6.) It is lined with a peculiar skin, termed the *mucous membrane*, which contains a number of little rounded bodies about the size of millet seed, termed *con-*

glomerate glands, whose tubes or ducts open into the mouth. These glands supply moisture to the mouth, which prevents its becoming dry and parched, and also helps to lubricate the food.

The *soft palate* is a moveable fold of mucous membrane and muscular fibre, forming a sort of curtain, which hangs down from the posterior edge of the bony palate. Its chief function is to prevent the food from passing into the nasal cavities during mastication, and to prevent the air from passing through the nose in drinking and suction.

The *uvula* is the small, conical-shaped, pendulous body which hangs from the middle of the lower edge of the soft palate. The curved *folds* of mucous membrane on each side of it are termed the *arches* or *pillars of the soft palate.*

The *isthmus of the fauces* is the space enclosed within the free margin of the palate above, the tongue below, and the pillars of the soft palate, and tonsils.

The *tonsils* are two almond-shaped, glandular bodies situated on each side of the *fauces.* Their inner surfaces contain twelve to fifteen orifices. The chief function of the tonsils is to *lubricate* the food.

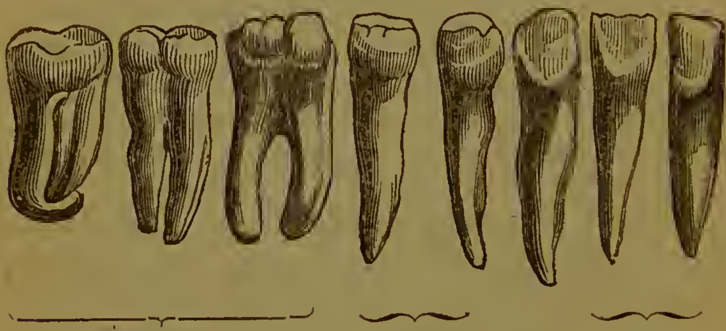


Fig. 2.—HUMAN TEETH.

Permanent Teeth.—The adult human being is supplied with thirty-two teeth termed permanent teeth, which are arranged in two semicircular arches

at the outer edges of the upper and lower jaw-bones. They are inserted into corresponding sockets, or *alveoli*, in the dental arches (*gums*) of the jaw-bones. This mode of union, which somewhat resembles that of a nail in a piece of wood, is termed *gomphosis*. They are retained in their places by vascular tissue, which grasps the neck of the tooth. There are sixteen teeth in each row; each *row* is divided at its middle line into two equal sets of teeth, each *set* containing four kinds of teeth (shown in the diagram), as follows, commencing from the middle line:—two *incisors*, or cutting teeth; next, one *canine*, or *cuspid* tooth; then, two *premolars*, small molars, or *bicuspids*; and lastly, three *large molars*.

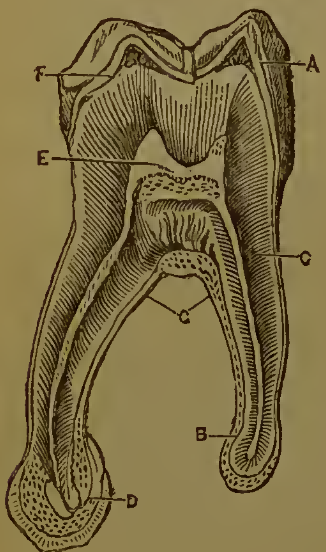
The Incisors, or cutting-teeth, are chisel-shaped, being bevelled from the interior, as shown in the diagram. They are used in cutting, and are largely developed in rats, rabbits, and other gnawing animals. They are inserted by one conical root or fang.

The Canine teeth are single-pointed teeth situated next to the incisors. They are largely developed in the flesh-eating animals, and enable them to seize and tear their prey. They are comparatively small in man. The upper canine are called the *eye*-teeth.

The Bicuspid, or false molar teeth, are double-pointed at the top, and are used in bruising and grinding the food. They are placed between the canine teeth and the large molars. The upper ones have one fang deeply set.

The true Molars are the principal grinding teeth; they have broad square tops, with four or five cusps or points, and two or three fangs or roots. The last molars do not usually make their appearance much before the period of adult age; they have, therefore, been termed *wisdom teeth*.

Structure of the Teeth.—Each tooth consists of three parts—the *crown*, or exposed part, which projects above the gum; the *fang*, or *root*, which is buried in the gum; and the *neck*, or grooved and slightly constricted portion, which separates the crown from the root. It has an internal cavity which contains the *tooth-pulp*. The tooth-pulp consists of nerves and bloodvessels. The tooth cavity has but one opening, at the base of the tooth, through which the nerves and bloodvessels pass into it.



A, Enamel.
B, G, D, Cementum petrosa.
F, C, Dentine.
E, Pulp cavity.
B, D, Fangs.

Fig. 3.—Section of Tooth.

The *mass* of the tooth is composed of a very hard tissue closely resembling bone, which is termed *dentine*. The *crown* of the tooth is covered by a still harder substance, the hardest substance in the body, termed the *enamel*. The *fang* of the tooth is *covered* with a very thin covering of bone, called *tooth-bone*, or the *cementum petrosa*. It is principally by this bony

covering that the teeth are joined so securely to their sockets.

A single tooth has been compared to a single *Haversian* system in bone: the tooth cavity corresponding with the *Haversian* canal; the dental tubuli corresponding with the canaliculi of true bone, and terminating in lacunæ in the cementum petrosa. (See "Bony Tissue.")

The Enamel is a hard, polished, bluish-white substance, consisting of little five or six-sided rods or prisms, about 1-4500th of an inch in diameter, placed

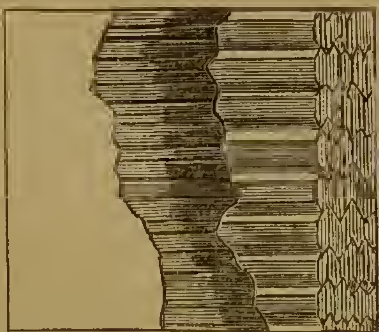


Fig. 4.—Microscopic Section of Enamel.
Showing hexagonal rods or prisms arranged endwise.

endways on the surface of the dentine. It is so hard that it will strike fire with steel. It forms a thin layer, covering the exposed surface of the tooth, giving it additional hardness and durability. When once damaged or broken it is doubtful, from its low vitality, whether it is ever repaired. It is, like glass, a bad conductor of heat, and is very easily cracked by a high or low temperature. Hence very hot or very cold liquids taken into the mouth tend to damage the teeth, and should be avoided by those who would preserve them in a state of soundness. When once

the *dentine* of the tooth is exposed, by the abrasion or destruction of the enamel, the tooth soon begins to decay. The enamel contains about 98 per cent. of earthy salts and only 2 per cent. of organic matter.

Milk Teeth.—At the time of birth the infant possesses twenty teeth, ten in each jaw, which are perfectly developed, but are completely covered or hidden by the gums. In about seven to ten months these teeth penetrate through the gums, and make their appearance: this is usually known as "cutting the teeth." If the child is strong and healthy, and kept sufficiently in the open air, it very rarely suffers; if, on the contrary, the child is not well, or is not kept out in the fresh air during a sufficient number of hours daily, its nervous system becomes exceedingly irritable, and the child not only suffers much, but is frequently attacked by convulsions (see Reflex Action) and dies. This is one cause of the great mortality of infants at this age. The teeth just described only last during infancy and childhood, being shed from the seventh to the thirteenth year; they are, therefore, termed *milk* teeth, or *deciduous* teeth. They are shed because of the growth of the permanent teeth, which, pressing on the roots of the milk teeth, interrupt their nutrition. Their fangs are consequently absorbed, and they drop out. The *milk* teeth consist, in all, of eight incisors, four canine, and eight molars.

Development of the Teeth.—The teeth do not properly belong to the true skeleton, being developments from the mucous membrane, and not from the jaw-bones.

A groove is first formed in the mucous membrane, called the *dental groove;* little papillæ are then developed; partitions, or septa, spring up in the *dental*

groove, separating the papillæ from each other. In this manner the dental groove forms *follicles;* these follicles close over the papillæ, forming sacs, termed *dental capsules;* the enclosed *papillæ*, which contain nerves and vessels, termed the pulp, are gradually *calcified* and converted into *dentine;* the crown becomes covered with *enamel;* and the *fang*, which is latest developing, gradually growing and receiving a

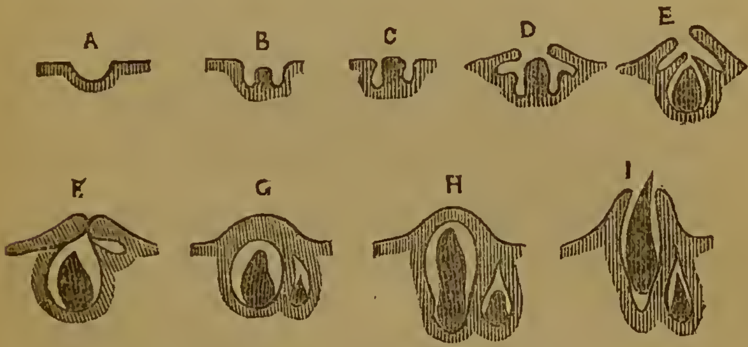


Fig. 5.—Development of Teeth.

A, B, C, D, E, show the formation of the dental groove, papillæ, and opercular (cover) flaps, which close the *groove*. F, G, H, I, show the formation of secondary cavity (of *reserve*) and *permanent* teeth. The cavity of reserve, in which the *permanent* teeth are formed, is the smaller follicle to the right of the original follicle or dental groove.

covering of *cementum*, begins to push the crown against the upper portion of the capsule and gum. The continued pressure of the tooth against the gum causes its absorption, and allows of the passage of the tooth. The tooth is then, in domestic language, "*cut*." The development of the *permanent* teeth always begins long before the child is born.

The Causes of premature decay are the use of excessively hot or cold substances, as described; want

of cleanliness in not removing, by the brush, the tartar and the portions of food which otherwise collect round the teeth, and tend to ferment, producing acid substances, which act injuriously on the enamel; indigestion, which causes the production of acids that dissolve out the earthy part of the tooth; the incautious use of acid medicines [I have known a patient to have all his teeth, previously quite sound, destroyed in a few months by taking acid medicines (as tonics) without due precaution]; *bolting* the food. When the food is not well masticated the organs of mastication, not being sufficiently exercised, do not receive their due supply of blood, and are, therefore, not properly nourished.

Insalivation is the process by which the food is thoroughly incorporated with the *saliva*, and other fluids, which are poured into the mouth from their respective glands. It proceeds simultaneously with mastication. Its purposes are—(1) to lubricate the food, and thus facilitate the process of swallowing; (2) to render it more permeable by the juices of the stomach; (3) to assist in changing the starchy portions of the food into sugar.

The Salivary Glands.—The spittle, or *saliva*, is secreted in large quantities by three pairs of glands, termed salivary glands, three of which are placed on each side of the face—the *parotid* glands, which are situated under the ears, a little towards the cheeks; the *sub-maxillary* glands, situated under the lower jaws; and the *sub-lingual* glands, which lie under the base of the tongue, and form a projection in the floor of the mouth, behind the frænum, under the front of the tongue. (Fig. 6.) The parotid ducts pour the saliva into the mouth by their orifices immediately over the second upper molar teeth. The sub-maxillary ducts

discharge their saliva into the mouth by two ducts opening by the side of the frænum of the tongue. The sub-lingual glands have several ducts, opening into the mouth at the sides of the lower part of the tongue, between it and the lower jaw. It is calculated, about three pints of saliva per day are secreted by the salivary glands. The quantity required varies with the kind of food. Juicy substances, as well as cooked meat, require 40 to 50 per cent. of their weight of saliva; dry, hard biscuits require as much as 150 per cent., or one-and-a-half times their own weight of saliva; while, on the other hand, some substances, as some juicy fruits, require as little as 4 or 5 per cent. of saliva. The *saliva* is poured out in greatly increased quantities, in consequence of *reflex* action, directly a substance is brought into contact with the tongue, or the walls of the mouth; also in certain cases of mental emotion, excited by hunger or by the odour of food. All have experienced the sensation known as the "*mouth watering*" at the sight, smell, or recollection of savoury food. Its flow is greatly increased by the movements of mastication; also, to a certain extent, by speaking. Certain medicines and poisons, as mercury, exercise a specific action on these glands, increasing the quantity of the secretion to many quarts per day. Fear and other painful emotions sometimes very greatly diminish the secretion, causing the mouth to become parched and dry. (See "Structure of Glands.")

Properties of Saliva.—The saliva, or *spittle*, is a clear, colourless, transparent, slightly viscid, and sometimes frothy liquid. It is at first slightly opalescent, from the presence of mucus and of epithelial scales, derived from the mucous lining of the mouth. It contains a peculiar active principle termed *diastase*,

ptyaline, or *salivine*, which exercises a powerful action on starch, changing it into grape sugar. The saliva of the *parotid glands* also contains a peculiar salt, called the sulphocyanide of potassium, which has been termed *rhodankalium*. Saliva has the following composition, according to the analysis of Frerichs:—

COMPOSITION OF SALIVA.

Water		. . . .	994·10
Solid	1·41	Salivin	5·90
	2·13	Epithelium and mucus .	
	0·07	Fat	
	0·10	*Sulphocyanide of potassium*	
	2·19	Fixed salts . . .	
			1000·00

Its specific gravity is 1004 to 1007; but both its specific gravity and composition vary slightly in different persons.

M. Lassaigne tried the following experiments on a cow, with the object of determining the relation between the *kind* of food and the *quantity* of saliva secreted:—He selected four kinds of food, portions of each of which he weighed accurately. An incision was made in the *œsophagus* of the cow. The several portions of *weighed* food were then separately given to the cow to be masticated and swallowed. As they arrived at the incision in the œsophagus, on their way to the stomach, they were collected, removed, and *re-weighed*; the difference in their respective weights after mastication, as compared with their weights prior to mastication, indicated the respective quantities of saliva used in each case. Thus,—

100 parts of	*green* stalks and leaves	absorbed	49	parts of *saliva*.
,,	oats	,,	113	,,
,,	barley-meal	,,	186	,,
,,	hay	,,	400	,,

Deglutition (from L., *de*, down, and *glutio*, I swallow) is the process by which the food is forced down the *pharynx* and *œsophagus* into the stomach.

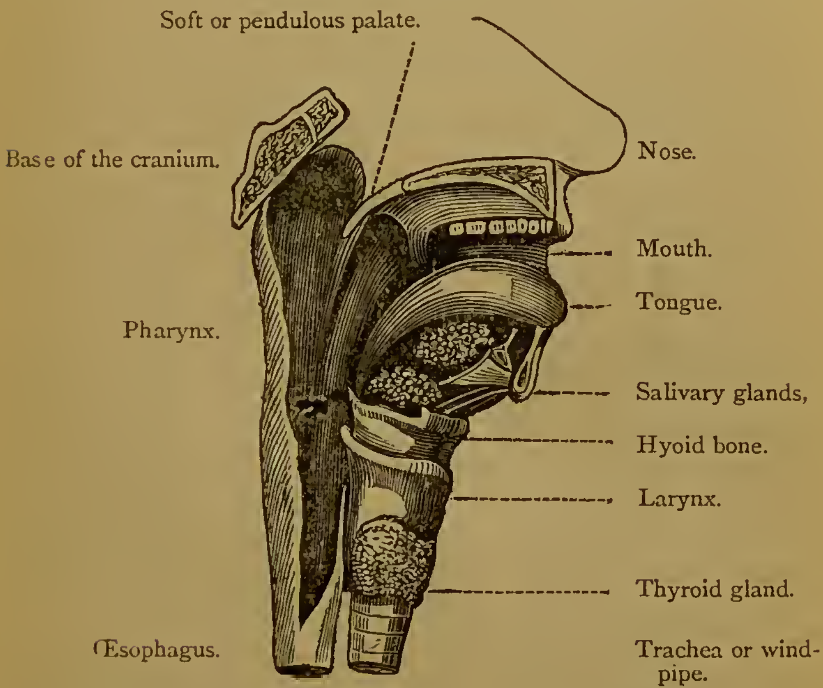


Fig. 6.—Vertical Section of the Throat and Mouth.

The chief organs of deglutition are the mouth, tongue, hard and soft palate, pharynx, and œsophagus or food-pipe.

Let the reader *masticate* a piece of food, and carefully observe the following stages in the act of swallowing or deglutition, as they proceed in his own person :—

1. The *masticated* food is mixed with the saliva, and formed into a *bolus* or ball by the action of the

tongue; the tongue then assumes a grooved shape, and conveys the bolus to the back of the mouth, squeezes it against the hard palate, and obliterates the cavity of the mouth; the soft palate is pushed backwards against the back of the *pharynx*, which is thus shut off from the cavity of the nose, into which the food would otherwise enter. The *larynx* is simultaneously drawn under the base of the tongue; the base of the tongue and the food, aided by certain muscles, press down the *epiglottis*, thus closing the aperture of the windpipe, and preventing the passage of the food into it.

2. The *bolus* passes from the *pharynx* into the œsophagus, where it is seized by the middle and inferior constrictor muscles of the œsophagus, which, by a wave-like motion, force it downwards. Simultaneously the tongue resumes its ordinary position, the *epiglottis* springs up by its elasticity, reopening the *trachea*, or windpipe, which also returns to its normal position; and respiration, which is interrupted during the first stages of deglutition, is resumed.

3. The food passes into the stomach.

The reader will have observed that the first stage of this process, which is performed in the mouth, is purely *voluntary*. The second stage is *involuntary*, though we are perfectly conscious of the presence of the food, and of the action which is proceeding. This stage of the process has therefore been described as *automatic*, a term applied by physiologists to designate *involuntary* but *conscious* action. The last stage of the process by which the food is passed into the stomach is purely *reflex*—that is, it is performed *involuntarily* and *unconsciously*.

That solid or semi-solid substances do not, in the process of swallowing, *fall* down the *œsophagus* by the

mere action of gravity, is rendered evident by the difficulty which most persons, at first, experience in swallowing pills. The general impression prevails that a pill is difficult to swallow because it is *too large*, whereas the real difficulty arises from its being *too small*. Pills are, in general, so small that the constrictor muscles of the *œsophagus* can seize hold of them only with difficulty. This is easily proved by the facility with which a small plum or cherry is swallowed, in spite of all our efforts to prevent its passing into the stomach, should we inadvertently allow it to get to the *back* of the mouth.

When the *œsophagus* is weakened or *paralyzed* before death, so that its muscles cannot act, the food falls into the stomach by the mere action of gravity, with a deep sound resembling that of a stone into a well. In the case of the horse and many other animals, the food, during the first portion of its course, is forced upwards in opposition to the force of gravity. Man also swallows against gravity when he performs the feat of swallowing in the position described as "standing on his head."

The Pharynx (from Gr., *pharugx*, gullet), (see Fig. 6) is a funnel-shaped musculo-membranous sac or tube, communicating at its upper and larger part with the cavities of the mouth and nose, and terminating at its *lower* end in the *œsophagus* or food-pipe. It extends from the base of the skull down to the fourth or fifth vertebræ (bones) of the neck. It is about 4½ inches long. Its *upper* extremity is about two inches in diameter, and its *lower*, or œsophageal end, rather less than one inch in diameter.

It is chiefly composed of three pairs of muscles, three on each side,—the superior, middle, and inferior *constrictor* muscles. It is lined *internally* by *mucous*

membrane, and is covered externally with *fibrous* membrane. It is situated immediately behind the larynx, or top of the windpipe, *over the entrance* of which all the food must pass *before* reaching the pharynx. If, therefore, the *larynx* be kept open by talking or laughing during the process of swallowing, the food will pass into it, only to be expelled after most inconvenient and violent fits of coughing. It will be observed that the *pharynx* serves the double purpose of conducting air through the mouth and nose to the *larynx*, and food through the mouth to the *œsophagus*. In *deglutition* the food has not only to be *conveyed* into the stomach, but to be *prevented* from passing *upwards* into the cavity of the nose, or *downwards* into the windpipe.

The Œsophagus (from Gr., *oiso*, I shall carry, and *phago*, I eat), or food-pipe, is the musculo-membranous tube commencing at the lower end of the *pharynx*, and terminating, after a somewhat tortuous course, in the *cardiac pouch* of the stomach (see Figs. 6 and 7). It commences at about the fourth or fifth vertebra, and, after perforating the diaphragm, enters the stomach opposite the tenth dorsal vertebra. The walls of the œsophagus are thick, and consist principally of an outer *longitudinal* layer of muscular fibre, and a much thinner inner layer of *circular* muscular fibre. The upper part of the œsophagus contains *striped* or *voluntary* muscular fibre; the lower part is made up almost entirely of *involuntary* or *unstriped* fibre. It is lined with *mucous* membrane, which is well studded with glands, and covered with thick *squamous* epithelium, and is invested externally with a coat of *areolar* or *fibrous* tissue.

The sides of the œsophagus wrinkle longitudinally, and collapse or fall together when food or drink is not passing down it. The pharynx, on the contrary, is

always open to receive air through the mouth and nostrils.

Suction.—The swallowing of liquids, at least until they have entered the œsophagus, is effected by entirely different means from those which obtain with regard to solid food. Observe what takes place when you drink out of a cup or a glass: you apply your lower lip to the side of the cup, so as to form with it an *air-tight* junction,—the tongue filling the whole of the mouth, so as to *obliterate* its entire cavity,—and the upper being placed in or immediately over the liquid. Simultaneously with this you press your soft palate back against the walls of the *pharynx*, so as to prevent the air from entering the mouth through the nose. You then withdraw and depress your tongue, and, by means of certain muscles, draw the top of the throat downwards and forwards, by which a *vacuum* is produced. The air in attempting to rush in *presses* on the surface of the liquid, and *drives* it forward into the mouth and pharynx to fill the *vacuum* thus produced. A similar operation is performed by the infant when suckling. These operations are very similar to that of the common *syringe*, the tongue, to a certain extent, playing the part of the *piston*. They also very closely resemble the action of a common flexible, elastic, vulcanized india-rubber ball. If the ball be compressed by squeezing its sides together, so that its internal cavity is obliterated, its small aperture being placed under water, on removing the pressure the elasticity of the walls forces them out to their original position, producing a *vacuum*, into which the water, propelled by the pressure of the atmosphere, immediately rushes, until it fills the interior cavity of the ball.

Chymification, or Stomach Digestion.—The

food, duly prepared by mastication and insalivation, passes into the stomach by its *cardiac orifice*, and coming into contact with its walls, stimulates them to perform certain *mechanical* movements, and to *secrete* and *discharge* into its cavity a peculiar *solvent* fluid, termed the *gastric juice*. A portion of the food contained in the stomach is dissolved by the *gastric juice*, and passed by absorption through the coats of the veins directly into the blood. Another portion, consisting of starchy matter which has been converted into sugar by the action of the saliva, is also dissolved and similarly absorbed; but the greater portion is converted into a gruel-like semi-fluid or pulpy mass, termed *chyme*. The *chyme* is then driven forward by the mechanical contractions constituting the *vermicular motion* of the stomach, and passing through the *pyloric valve* at its lower and smaller end, reaches the *duodenum*, or first portion of the *small* intestines, there to undergo further changes, which will be explained under the head of *Intestinal* Digestion.

The Stomach is a somewhat conical, curved, musculo-membranous bag or pouch, capable of holding, when full, from three to five pints of food (Fig. 7). It consists of *four* distinct coats—1, an *outer*, *serous*, or *peritoneal* coat; 2, a *middle* or *muscular* coat, consisting of longitudinal, transverse or circular, and oblique muscular fibres; 3, a *sub-mucous* or *areolar* coat; and 4, an *inner* or *mucous* coat. The first serves to strengthen and protect the organ; the second to perform the *vermicular* movements necessary to rapid and perfect digestion; the third to attach the *mucous* membrane to the muscular coat, and form a matrix in which the minute gastric arteries and the nerves *break up* and *ramify;* and the fourth, or last, to *secrete* the various juices by which gastric or stomach digestion

is effected. Many writers subdivide the coats just mentioned into two or more separate coats, thus describing the stomach as consisting of five or six coats —an outer *fibrous* coat; a longitudinal, a transverse, and an oblique *muscular* coat; a sub-mucous, areolar, nervous, or *vascular* coat; and a *mucous* coat.

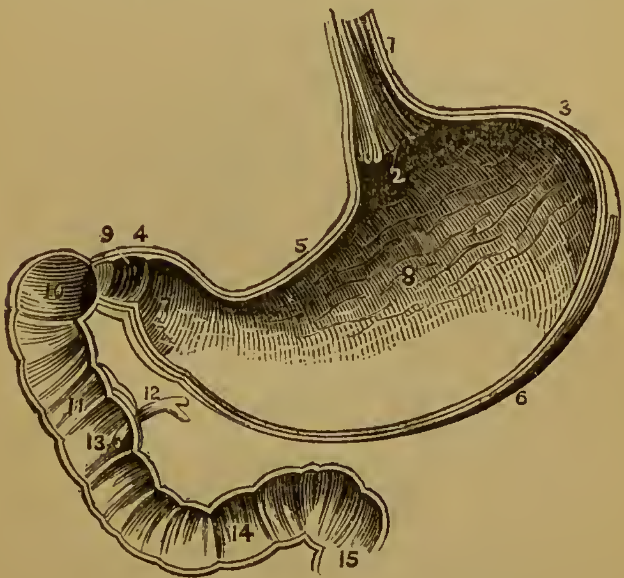


Fig. 7.—Section of Stomach.

1. Œsophagus.
2. Cardiac orifice.
3. Cardiac pouch.
4. Pyloric end or pouch.
5. Lesser curve.
6. Greater curve.

7, 8. Interior, showing *rugæ*, or *folds*.
9. Pylorus.
10, 11. Duodenum, showing *valvulæ conniventes*.
12, 13. Common bile duct.
14, 15. Intestine (jejunum).

The stomach has *two orifices*, or openings—the *cardiac orifice*, by which it communicates with the œsophagus; and the *pyloric orifice*, by which it communicates with the *duodenum*. When moderately distended it has an upper *concave border*, termed the

lesser curve; and a lower *convex border*, termed the *greater curve.* When the stomach is quite empty its walls collapse, these curves entirely disappear, and it hangs down from the *œsophagus.* It is slightly *constricted* or narrowed in the middle by the *notch* which divides it into a *cardiac* and a *pyloric* pouch.

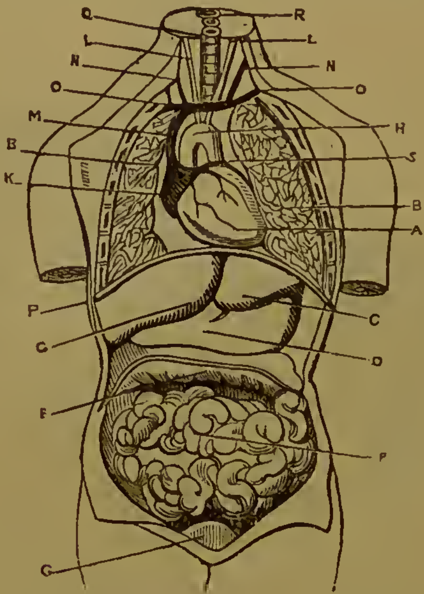


Fig. 8.—Front View of the Organs of the Thorax and Abdomen.

A. Two ventricles of the heart.
B, B. Right and left lung.
C, C. Right and left lobes of liver.
D. Stomach.
E. Transverse colon (large intestine).
F. Small intestine.
G. Bladder.
H. Aorta.
K. Right auricle.
L, L. Right and left carotid arteries.
M. Superior vena cava.
N, N. Right and left jugular veins.
O, O. Right and left sub-clavian veins.
P. Diaphragm.
Q. Windpipe.
R. Œsophagus.
S. Left auricle.

The *cardiac pouch*, so called from its vicinity to the heart, is the only part of the stomach supplied with *oblique* muscular fibre.

Situation of the Stomach.—The stomach (see D, Fig. 8) lies across the upper part of the *abdominal cavity*, its larger or *cardiac* extremity lying on the left side in contact with the lower surface of the diaphragm (P), and its lesser or *pyloric* extremity extending a little forward towards the right side underneath the liver (C) as far as the right kidney. Its lower border lies parallel with the transverse colon (E). It is attached to the *spleen*, which lies at its left or cardiac extremity, by a process of the *peritoneum* termed the *gastro-splenic omentum;* to the *liver* by the *gastro-hepatic*, or the *lesser omentum;* and to the *colon* by the *great omentum.* These *omenta*, or apron-like processes of the *peritoneum*, are seen very beautifully in the newly killed sheep displayed in the butchers' shops, presenting the appearance of delicate transparent membranes, covered with a network of fat, the meshes of which are more or less close.

The upper end of the stomach is attached to the *diaphragm* at the point at which it is penetrated by the *œsophagus;* its lower end is very moveable, and is connected with the *duodenum*, which is fixed to the posterior wall of the belly. Being attached chiefly by its two extremities, it possesses considerable mobility, and readily adapts itself to all the changes of position required by the varying amounts of food it may contain, and to the exigencies of bodily action.

The Serous coat of the Stomach is derived from the *peritoneum*, or lining membrane of the abdomen, which invests the stomach, and gives off the various processes or *omenta* previously referred to. It consists of a layer of *areolar* tissue covered by *basement*

membrane, which is lined with a single layer of flattened hexagonal *epithelial* cells.

The Muscular coat of the stomach consists of three layers of unstriped or organic muscular fibre —1, an outer or longitudinal layer; 2, an inner, transverse, or circular layer, much thicker than the preceding; 3, an oblique layer. The layer of oblique muscular fibre is only found at the larger or *cardiac* end of the stomach, and lies under the transverse layer, and in immediate contact with the mucous coat. The muscular coats of the stomach are continuous with those of the *œsophagus* and intestines.

The Mechanical, Vermicular, or Peristaltic action of the stomach is performed through the agency of the muscles just described, as follows :— 1. At the close of each act of swallowing the lower muscular fibres of the œsophagus contract with such force as to entirely obliterate the cardiac orifice : this constriction lasts a few moments. 2. Very shortly, in a few moments after food has been received into the stomach, a slight constriction of the transverse fibres commences at the *cardiac* end of the stomach : this constriction is gradually transmitted to the pyloric end, becoming more rapid and powerful after passing the *notch* which divides the stomach into the two pouches ; the constriction having arrived at the *pylorus* a moment of relaxation follows, after which the action is repeated.

Towards the end of the process the stomach becomes very much constricted at its *notch*, producing what is described as *the hour-glass constriction*, and the muscular action of the stomach is almost entirely confined to the *pyloric* pouch, the *cardiac* pouch remaining nearly if not quite inactive.

Dr. Beaumont found that the food made a complete

revolution round the walls of the stomach, passing from the *cardiac* to the *pyloric* end and back again in from *one* to *three* minutes. The mode in which this revolution is effected is most probably the following:—A constriction of the stomach *commences* at the *cardiac* orifice, becoming more powerful as it proceeds *towards* the *pylorus*. This constriction may be compared to a ring travelling from the large to the small end of the stomach (Fig. 9), and pushing the food in contact with the walls of the stomach before it; thus establishing a *peripheral* or outer current of food, moving towards the pylorus.

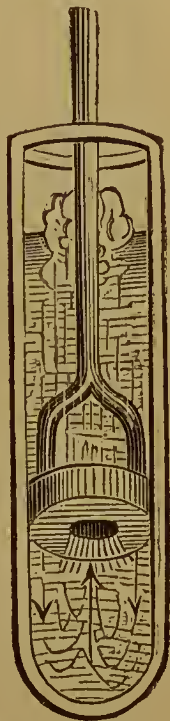


Fig. 9.—Diagram illustrating Gastric Peristalsis.

The perforated piston or ring is supposed to be moving downward in a closed tube containing liquid, thus producing an *axial* upward and a *peripheral* downward current.

The food, having arrived at the *pyloric* or closed end of the stomach, and being still pushed from behind and unable to move forward, is forced into the line of least resistance, and commences a *return* or *backward* movement in the direction of the *axis* of the stomach—that is, of the *central* line joining its *cardiac* and *pyloric* orifices. In pursuing this *backward* direction the food is *returned* to the cardiac orifice, *again* to repeat a similar series of movements, *until* it is sufficiently *dissolved* to pass through the pyloric valve, or

until this valve becomes wearied of further resistance to its progress. In this way a *peripheral* forward and an *axial* return current of the food are set up by the *vermicular* motion of the stomach.

The Mucous coat of the Stomach, which forms the *fourth* or *innermost* coat, derives its name from the circumstance of its being constantly covered by a thin, transparent, slimy, slightly viscid fluid, termed *mucus*. The *mucous*, sometimes termed the *villous* coat of the stomach, is by far the most important and interesting of the four gastric membranes. It has a soft, velvety appearance, and is of a pinkish-white

Fig. 10.—Mucous Membrane of the Stomach.

colour when the stomach is empty; but when the stomach is full, during digestion, it is of a brilliant red hue. Its surface is greater than that of the other membranes, in consequence of which it collects in *rugæ* or *plicæ* (*folds* or *wrinkles*) when the stomach is empty. These *folds* in general run longitudinally; they disappear when the stomach is fully distended with food: it is said they are most distinctly seen in persons who have died suddenly. The *rugæ* are familiarly seen in *tripe*. The *mucous* coat consists of—1, a layer of *basement membrane;* 2, an inner layer of *epithelial cells.* Its surface is greatly increased by the

gastric follicles, or *tubuli*, which are simply foldings in, or recesses in the surface of the membrane; the number of these tubuli, or follicles, is immense, being estimated at upwards of 5,000,000. Their principal function is supposed to be the secretion of the *gastric juice*. If the mucous membrane be stretched, and its *free* surface be carefully examined with a magnifying glass, it is seen to be covered with small shallow, polygonal pits or depressions, termed *alveoli*, into the floor of each of which the mouths of six or eight of the stomach or *gastric tubuli* open. (See Figs. 10 and 11.) Rudimentary villi exist towards the pyloric end of the stomach. In addition to the gastric tubuli or glands, its surface is studded, though somewhat sparingly, with *lenticular glands* (Fig. 15, g), similar to those of the intestines: their function has not yet been determined. The mucous membrane is doubled or folded into a ring at the pylorus, forming the pyloric valve.

The Gastric Tubuli, or **Follicles,** are minute vertical tubes in the mucous membrane; they are about 1-25th of an inch in length, and 1-350th of an

Fig. 11.—Gastric Follicle.

Showing *columnar epithelium* in middle and upper part of tube, and *glandular epithelium* in lower part of tube, adhering to wall of *basement membrane*.

inch in diameter. Their length is thus about ten or twelve times their diameter. They consist of an outer

wall of fine *basement* membrane, and an inner lining of *epithelium*, which is *glandular* or *spheroidal* at the bottom of the *follicle*, and *columnar* towards its upper portion. The *glandular* epithelium filling the lower part of the *follicles* consists of *oval nucleated* cells, the largest of which are about 1-1200th of an inch in diameter. The *gastric follicles* have in general a cylindrical shape, are rounded and closed at their bases, and are slightly expanded at their upper and open extremities or mouths. They are, however, very frequently slightly expanded at their lower extremities, having a somewhat flask-like shape, and they not unfrequently split up or divide, at their lower or closed extremities, into three or four separate microscopic pouches or sacs. They are embedded in the meshes of the *sub-mucous areolar* tissue which forms their *matrix*. The *gastric follicles* are now supposed by most modern physiologists to secrete *pepsin*, the peculiar *organic* principle of the *gastric juice*.

Capillaries of the Gastric Follicles. — Two systems of capillary network may be described as belonging to the gastric follicles—1, a *parietal* network, which surrounds the walls of the *tubuli*, or *follicles*; 2, a *superficial* network, which ramifies through the *surface* of the *mucous* membrane, and occupies the *interspaces* or ridges between the mouths of the follicles, and the capillaries of which encircle these minute orifices.

The *parietal* network, which surrounds the walls of the follicles at all parts of their height, is composed of exceedingly minute capillaries, 1-5000th to 1-4000th of an inch in diameter. Its meshes are somewhat *oblong*, resembling those in the capillary network of striped muscular fibre, and about 1-250th to 1-100th of an inch in length.

The second or *superficial* network consists of capillaries about 1-2500th of an inch in diameter, or about double the diameter of the *parietal* capillaries just described. They ramify through the surface of the *mucous* membrane, encircling the *mouths* of the follicles with their loops, and occupying the *ridges* or interspaces between them: they *inosculate* very freely with,

Fig. 12.—CAPILLARIES OF GASTRIC FOLLICLES.

a. Small *artery* of plexus in sub-mucous tissue.
t. *Parietal capillaries* around walls of follicles.
r, r. Larger capillaries, forming *superficial* network on ridges separating mouths of follicles.
v. Veins formed by branches of superficial network, ending below in sub-mucous venous plexus.

and are also continuous with, the *parietal* capillaries of the follicles; their *meshes* are about half the size of those of the latter, varying from 1-800th to 1-300th of an inch in diameter.

The minute *arteries*, about 1-1800th of an inch in diameter, from which these capillaries are derived, ramify in the *sub-mucous areolar* tissue, *pass up* verti-

cally between the exterior walls of the follicles, giving off—1, the *parietal* network which surrounds the gastric tubuli; then forming, 2, the *superficial* capillary network previously described; 3, the *radicles of the veins*, formed by the union of the superficial capillaries, at first about 1-1500th of an inch in diameter, which again uniting, produce, by repeated junctions, minute *venous* branches, 1-500th to 1-400th of an inch in diameter. These veins pass vertically down between the follicles, through the substance of the mucous membrane, to the sub-mucous areolar tissue, in which they join the larger venous trunks which ramify there.

As a consequence of these arrangements the blood takes the following *course* during its circulation through the *mucous* membrane of the stomach:—1, it passes *from* the arteries in the *sub-mucous areolar tissue* (*a*, Fig. 12); 2, *up* the minute *parietal* capillaries (*t*) surrounding the *gastric follicles;* 3, *into* and *through* the larger *superficial* capillaries (*v*) encircling the mouths of the tubuli; 4, *into* and *down* the veins between the tubuli; 5, *into* the veins (*v*) sub-lying the mucous membrane, by which it leaves that membrane.

These veins collect the blood from the stomach, and ultimately pass it into the *portal* vein. The portal vein distributes it through the liver, where it affords *bile.* It is then collected and passed out of the liver by the *hepatic* vein, which discharges it into the *vena cava*, by which it is returned to the heart.

The Gastric Juice (from Gr. *gaster*, the stomach), when pure, is a clear, limpid, transparent, colourless or pale straw-coloured, structureless liquid, having a peculiar odour resembling that of the blood, and a slightly saline and sour taste, which is poured out of the *mucous* or lining membrane of the stomach during digestion. It has a slightly *acid* reaction, reddening blue test-

paper, effervesces slightly with alkaline carbonates, and does not coagulate on being heated. It possesses powerful *antiseptic* qualities, and is capable of arresting putrefaction even after it is set in, as shown in the digestion of *high* game, which is eaten in a state of incipient putrefaction.

At a temperature of 90° to 100° F. it possesses great solvent power over the *protein* or albuminous compounds, which it rapidly dissolves, reducing them all to a compound termed *peptone*, which possesses certain common properties, whether formed by the solution of albumen, fibrin, or gluten. At a temperature of 120° and upwards, also at the ordinary temperature of the atmosphere, its *solvent* power almost entirely ceases. The *gastric juice* exerts but little or no power over the starch or gum of vegetable food. It sometimes dissolves or erodes through the coats of the stomach, especially in cases of sudden death by accident after a meal, and while digestion is proceeding; but it is said to exert little or no solvent power over living bodies, which accounts for the presence of living forms in the stomach, which would otherwise be impossible. This explanation is, however, scarcely consistent with other experiments. Dr. Harley attributes its non-action on the coats of the living stomach to the protective influence of the *mucus* by which it is covered. Gastric juice is *not precipitated* by mineral acids, alum, sulphate of copper, chloride of iron, ferrocyanide of potassium, or by heat. Salts of lead and bichloride of mercury throw down precipitates containing the organic principle when added to it. Salts of silver precipitate the chlorine. Strong alcohol precipitates the organic principle, and *destroys* the *digestive power* of the gastric juice, but when diluted produces no chemical change on it. It is said the *gastric*

juice is capable of *dissolving* 15 to 20 per cent. of its own weight of *finely divided protein* compounds; other physiologists estimate it at 5 per cent., or even less. It is calculated about twenty pints of gastric juice are secreted daily. In the case of a woman, Catherine Hutt, who suffered from gastric fistula, thirty-one pounds were secreted during twenty-four hours.

Composition of Gastric Juice.—It is difficult, if not impossible, to determine the exact composition of gastric juice. It is rarely if ever found *pure*, being almost constantly in a state of admixture with mucus, saliva, or other digestive fluids. It is even doubtful whether pure gastric juice has a definite chemical composition; it most probably varies, more or less, in composition according to the requirements of the food and the state of the system. The following table indicates the general plan of the composition of true gastric juice:—

$$\text{Gastric juice} \left\{ \begin{array}{l} \text{Water.} \\ \text{An acid.} \\ \text{Salts.} \\ \text{An organic ferment (PEPSIN).} \end{array} \right.$$

Considerable difference of opinion obtains among physiologists as to the nature of the principal acid constituent of gastric juice; some maintaining it to be *lactic* acid, others *hydrochloric* or *muriatic* acid, while others again have maintained that its acid properties are due to the presence of the acid *superphosphate of lime.* It has, however, been shown that the presence of either of these acids in the gastric juice will enable it to perform its solvent function. It is now generally admitted that *hydrochloric* acid is the acid most generally present, though sometimes *lactic* acid only is found in the stomach. The following is an analysis of the *gastric juice* mixed with saliva, from the stomach

of Catherine Kutt, who had a fistulous opening, situated between the 9th and 10th costal cartilages, into her stomach :—

COMPOSITION OF HUMAN GASTRIC JUICE (CONTAINING SALIVA).

Water	. . . .		994·40
Solids	Organic matter, Pepsin	3·19	5·60
	Chloride of sodium	1·46	
	,, potassium	0·55	
	,, calcium	0·06	
	Free hydrochloric acid	0·20	
	Phosphate of lime, ,, magnesia, ,, iron	0·12	
			1000·00

From this table it would appear that *gastric juice* contains about 0·3 per cent. of *pepsin*. The quantity of *pepsin* is probably much greater in the gastric juice of *carnivorous* animals. Schmidt found the gastric juice, of a portion of which the analysis has just been given, was capable of dissolving 2½ per cent. of *albumen;* that is, 100 grs. of the gastric juice from the stomach of Catherine Kutt would dissolve 2½ grs. of albumen. Until recently, the free *hydrochloric* acid of the gastric juice could only be separated by distillation, which required the application of heat. The supporters of the *lactic* acid theory contended that the *hydrochloric* acid, previously in a state of chemical combination, was set free during the process of distillation by the heat employed; but Professor Graham has proved the presence of *free* hydrochloric acid by his method of *liquid diffusion*, which does not require the application of heat.

Pepsin, gasterase, or the organic principle, or

ferment, of *gastric juice*, may be obtained by digesting the *mucous membrane* of the stomach of an animal in *cold* water. It was first obtained from the *mucous* membrane of the stomach of the pig, which greatly resembles that of man. The *pepsin* may be separated by careful evaporation of its aqueous solution, or by precipitation in white flocculi upon the addition of strong alcohol. *Pepsin* is an albumoid substance, very soluble in water, insoluble in alcohol; its solution does not *coagulate* when heated, but it loses its *digestive* power when heated to above 120° F. Its aqueous solution, when slightly acidified, possesses great *solvent* power over muscular fibre, &c. Hard-boiled eggs, beef, &c., when immersed in such a solution at a temperature of 100° F., are entirely dissolved, an *artificial* gastric juice being thus formed. Aqueous solutions of *pepsin* are precipitated by alcohol, corrosive sublimate, salts of lead, and solutions of tannic acid. When obtained by evaporating its aqueous solution, it forms a greyish viscid mass, having the appearance of an *extract*, and a faint odour resembling that of glue. *Pepsin* is now supposed by most physiologists to be secreted by the *gastric tubuli.* Pepsin has recently been prepared and used as a medicine to aid feeble digestion.

Chyme is a soft, greyish, viscid, pultaceous or porridge-like, slightly acid substance, produced by the action of the *gastric juice* and the *saliva* on the masticated food which has been submitted to the action of the stomach. It varies more or less in colour, consistence, and appearance, according to the nature of the diet. *Chyme* consists principally of the *fatty* and the *indigestible* portions of the food, of the *starchy* elements which have not yet been converted into sugar by the action of the *saliva*, possibly some *sugar*, and more or

less of the *peptone*, or dissolved *proteinous* substances that have escaped absorption (by *osmosis*) through the coats of the stomach into the veins. When examined by a microscope, muscular and vegetable fibre, starch grains, liquefied fat, and minute strings of tendon are plainly visible.

Peptone is the term applied to the solution of the *albumen*, *fibrin*, *casein*, or other *proteinous* compounds in *gastric juice*. It is said to be identical in character and properties, from whatever *albuminous* or *proteinous* compounds it may have been formed. It somewhat resembles *albumen* in some of its properties, and was therefore termed "*incipient albumen*" by Dr. Prout, but it differs from albumen in many of its most important characteristics.

When carefully evaporated it yields a yellowish-white, almost tasteless and inodorous solid substance, which is exceedingly *soluble* in water, but *insoluble* in strong *alcohol*. It is *not* coagulated by boiling or by the action of acids, like albumen ; and also differs from it in being easily absorbed and *assimilated* by the system. Its ultimate chemical composition is almost identical with that of the compounds from which it is derived. It forms *soluble* compounds with the alkalies. Its aqueous solution reddens blue litmus, and is precipitated by chlorine, tannic acid, and the metallic salts.

A saturated solution of *peptone* is enabled to dissolve an additional quantity of *albuminous* substance by the addition of water, and its *solvent* power is still more decidedly increased by the addition of acid, which thus seems to restore its original qualities to the gastric juice.

Dr. Brinton suggests that the action of the *gastric juice* on *protein* compounds very closely resembles the action of *water* in the formation of *hydrates*.

Artificial Digestion.—Procure *three* small bottles; introduce into each a small quantity of *artificial gastric juice*, made by dissolving *pepsin* in water slightly acidulated with *hydrochloric* acid. Also procure three small pieces of lean flesh-meat of equal weights. *Mince* one of the three weighed portions of meat *very finely*. Place the undivided portions of the meat in bottles 1 and 2, and the finely divided portion in bottle 3. Allow bottle 1 to remain perfectly *quiet* at the natural temperature of the atmosphere. Heat bottle 2 and its contents to 98° or 100° F. by means of a water bath, but be sure it is kept in a state of *perfect quiescence*, that temperature being maintained during the whole of the experiment. Warm bottle 3 and its contents to the same temperature (98° or 100° F.), but instead of keeping it in a state of *quiescence* keep it *well agitated* by continuous shaking; taking care that its temperature remains at the same point. Examine the contents of the bottles from time to time. In about one and a half to two hours the *minced* meat in bottle 3 will be found to be completely dissolved or *chymified*. The contents of bottle 2, which have been kept warm, will be found to be but slightly changed at the end of an hour, though the process of *chymification* will have fairly commenced; in about three hours nearly one-half of the meat will have been dissolved, but the complete *chymification* will not have been effected until nine to twelve hours after the commencement of the experiment. If the contents of bottle 1 be now examined they will be found to present no signs of *solution* or *chymification;* the meat will be found slightly softened by the maceration, but no more dissolved than if kept in water, especially if it were slightly acidulated, during the same period of time. Dr. Beaumont performed similar experiments to those

just described by means of the *natural* gastric juice, obtained from the stomach of St. Martin. He also compared the results with those of *natural* digestion as it proceeded in his stomach. Other investigators have obtained the *gastric juice* necessary for their experiments by various devices. One ingenious method consists in inserting small pieces of sponge into small hollow perforated metal balls, attaching the balls by string, and giving them to men and to inferior animals to swallow. The mechanical irritation of the ball against the *mucous* coat of the stomach causes it to pour out the *gastric juice*, which is absorbed by the sponge. The ball is then drawn out of the stomach by means of the string, the sponge removed, and the *gastric juice* squeezed out of it. The operation is then repeated until a sufficient quantity of *gastric juice* is obtained. If the quantity of meat in the bottle be too great, it will not dissolve unless *more* gastric juice be added.

The following inferences in relation to *natural* digestion may be drawn from the results of these experiments:—1. The drinking of large quantities of cold water, beer, or other liquids, by *reducing* the *temperature* of the stomach and the *gastric juice* below its natural standard, materially checks digestion. This effect is still further increased by the *dilution* of the gastric juice. 2. The swallowing of the food without due mastication *obstructs* and *prolongs* the process of gastric digestion, and materially increases the *labour* of the stomach. 3. The eating of *excessive* quantities of food not only *retards* the digestion of the actual excess consumed, but prevents the complete and perfect digestion of *every portion* of the entire quantity of food partaken of; so that a *small* quantity of food, well digested, would afford much more real nutriment than

a large excess, which is necessarily ill digested, because of the *insufficient* quantity of the *gastric juice* supplied by the stomach.

Dr. Beaumont inferred, from the results of some of his experiments, that the *whole* of the *gastric juice* was supplied by the stomach within twenty to forty minutes of the commencement of the process of digestion.

What Dr. Beaumont saw in the Stomach.—Our most accurate knowledge of what takes place in the stomach is derived from the observations of Dr. Beaumont, of America. In 1822 a healthy young Canadian, named Alexis St. Martin, met with a gunshot accident, a portion of his lungs, diaphragm, ribs, and outer integuments being blown away, and a *perforation* made into his stomach. He became a patient of Dr. Beaumont, and in about a year from the time of the accident, he, through skilful treatment and the possession of a sound and unimpaired constitution, had entirely recovered. The *perforation* in his stomach, however, still remained—about 2½ inches in diameter. At first, even after recovery, the food escaped through this aperture, unless it was closely covered by a compress; ultimately a sort of *valve* was formed by a fold of the *mucous* membrane of the stomach. This fold prevented the contents of the stomach escaping externally, but admitted of being easily opened by the finger when pushed from without, exposing the inside of the stomach and its contents to the view of the observer. Dr. Beaumont afterwards, during a period of two years, conducted a very extensive series of experiments on digestion, on the person of this St. Martin, who was in a high state of health.

On pushing back the valve referred to in the stomach of St. Martin, it was observed—1, that when

his stomach was empty, its interior was of a *pale pinkish* white colour, and did *not* contain any *gastric* juice; 2, that on the entry of the food or any mechanical body, its walls immediately became charged with blood, assuming a much *deeper* pink or *red* colour, and that little globules of *gastric* juice, which trickled down and mixed with the food, immediately began to ooze out of its walls; 3, that on the food entering the stomach, a gentle onward motion, the *vermicular* motion, was immediately set up by its walls, the motion becoming more rapid and powerful as digestion proceeded; 4, that the food was gradually converted into a gruel-like, pulpy mass termed *chyme*, which disappeared through the pyloric orifice. Dr. Beaumont further observed, that though the exudation of gastric juice immediately followed the introduction of any solid body, yet it soon ceased if such body did not act as food. In the course of his observations he was led to infer, that the quantity of gastric juice secreted was not determined by the quantity of food taken, but by the quantity of food required by the wants of the system; so that the surplus food, after fatiguing and irritating the stomach and intestines, and producing more or less feverishness and restlessness, was passed out of the body *undigested*. He also observed, that in certain states of the system, more particularly in fever, the mucous coat remained red and dry, and incapable of supplying gastric juice, thus showing the uselessness of attempting to administer solid food in cases of fever. He also noticed the effect of various mental emotions —as anger, fear, anxiety, &c.—in disturbing the state of the *mucous* membrane of the stomach, vitiating its secretions, and interrupting or injuring its functions.

Dr. Beaumont always found, that after St. Martin had been indulging in spirits for a day or two, though

not to a degree usually termed excessive, his stomach became covered to a greater or less extent with dryish red-looking patches. In these cases St. Martin was himself entirely unconscious of any deterioration in his health.

The Bloodvessels of the Stomach. — The *arteries* of the stomach are derived from the *cœliac axis.* This vessel is given off from the *aorta* opposite the first lumbar vertebra, forming a short, thick trunk about half an inch long, which divides into three large branches — the *gastric* artery, which supplies the *stomach;* the *hepatic* artery, which supplies the *liver;* and the *splenic* artery, which goes to the *spleen.*

The *gastric artery*, after leaving the *cœliac axis*, divides into two branches, which pass nearly horizontally, right and left, along the *upper* and *lesser* curvature of the stomach. These branches give off numerous smaller arteries, which pass *vertically* down the walls of the stomach, and *anastomose* with the vertical branches given off by the *right* and *left gastro-epiploic* arteries, which pass *below* the stomach, taking a generally horizontal direction, and following its *lower* and *greater* curvature.

The *right gastro-epiploic* artery (from Gr., *epiploon*, the caul) is derived from the *hepatic* artery. The *left gastro-epiploic* artery originates in the *splenic* artery. These arteries pass along the *lower* and *greater* curvature of the stomach—the former from the *right*, the latter from the *left*,— and *anastomose* or join each other so as to form one continuous vessel. They give off numerous branches to the stomach and adjacent parts.

The *arteries* and *veins* of the stomach are exceedingly *tortuous*, and are very *loosely* connected with its walls. They therefore very readily adapt themselves

to any position or degree of distension of that organ.

The smaller arteries and veins form two *flattened networks*, which lie in the meshes of the *areolar submucous tissue*, and completely encase the stomach within their *vascular* structure.

The *gastric veins*, in general, correspond with the arteries. They empty themselves into the portal vein, which distributes the *venous* blood from the organs of digestion through the substance of the *liver*, for the purpose of *bile-making*.

Lymphatics of the Stomach.—The stomach is supplied with *two* sets of lymphatics—a *superficial* set, consisting of smaller vessels which lie immediately *outside* the muscular coat and *beneath* the peritoneum; and a *larger* and *deeper* set, which ramifies in the *submucous* coat. The lymphatics of the stomach anastomose very freely with those of the adjacent organs.

Nerves of the Stomach. — The stomach is very abundantly supplied with nerves from the *sympathetic* and the *cerebro-spinal system*. The sympathetic nerves are derived from the semilunar ganglia and the *solar* plexus.

The *cerebro-spinal* nerves supplied to the stomach consist of the *right* and *left* terminal branches of the *pneumo-gastric nerve*. The *right* nerve is distributed to the *posterior* surface, and the *left* nerve to the *anterior* surface of the stomach.

When these nerves are divided the stomach loses the power of performing its muscular movements. They would therefore appear to be the *motor* nerves of the stomach. Some physiologists contend that they also supply the *nervous* influence by which the *gastric juice* is secreted, but the opinions of experimenters are divided on this point. The experiments of Dr. John

Reid would appear to prove that it is possible to sever the *pneumo-gastric* nerves of dogs without stopping the secretion of the gastric juice. Several dogs on whom he performed this operation continued to live a considerable period after its performance, when the necessary care and attention were given to their feeding.

When the *pneumo-gastric* nerves are divided, the *vermicular movements* of the stomach immediately cease. If a current of electricity be now passed through the ends of these nerves the vermicular movements will be repeated. Should the stomach contain food, *gastric juice* will also be secreted. Also if a current of electricity be passed through the *pneumo-gastric* nerves of an animal which has *recently* died, the movements of digestion will be imitated.

The stomach is most intimately connected by *sympathy* with the rest of the system. This is due to its abundant supply of nerves. A sudden blow on the stomach, especially after a full meal, when it is somewhat distended, will sometimes produce death, even when no apparent injury is done to the part struck. Death is, in this case, probably due to the *nervous shock* received through the *cœliac plexus* of the sympathetic nerves of that region.

Grief, anxiety, anger, great mental labour, or any powerful emotion, tends to *arrest* or *impede* digestion by withdrawing or abstracting the *nervous* force necessary to the performance of perfect digestion.

Osmosis (from Gr., *osmos*, impulse) is the term applied to the process by which two liquids separated by an intervening membrane, or a porous solid, penetrate or traverse its substance, and mix together on its opposite side.

Experiment. — Procure a wide-mouthed glass

funnel, with a long stem of small bore; tie a piece of bladder over the wide opening of the funnel; invert it, and fill the body of the funnel and a portion of its stem with alcohol; then place it in a tumbler or tall glass jar of water, so that the water in the tumbler and the spirits in the tube shall stand at the same level. (Fig. 13.) The liquid in the interior of the funnel will gradually rise, against gravity, until at last, if it be left a sufficient time, the tube of the funnel will be entirely filled, and the liquid will run over. In this case the *water* from the exterior vessel passes *through* the substance of the bladder *into* the funnel. Simultaneously a minute and almost inappreciable quantity of *alcohol* passes in the *opposite* direction from the funnel into the water in the jar. A similar action also takes place if a solution of sugar be substituted for the alcohol. If, however, a film of collodion be substituted for the animal membrane the action is *reversed*, and the sugar or the alcohol passes *out* of the funnel into the water contained in the tumbler.

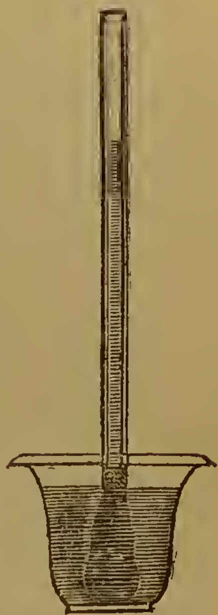


Fig. 13.

Theory of Osmosis.—Probably the action termed *osmosis* is due to many causes, which vary with the circumstances under which it is set up. The following *theory* is sufficient to explain *osmosis*, as illustrated in the experiments on sugar and alcohol just described:—1. The force of the *adhesion* between the *water* and the *bladder* is greater than the *adhesion* between the

spirits and the *bladder;* the water, therefore, wets the bladder with facility, while the spirits wet it only with great difficulty. 2. The bladder being thoroughly wetted by the water causes it to pass through its substance by mere *capillary* attraction. 3. The water having permeated the substance of the bladder, and arrived at its upper surface, is gradually removed by *liquid diffusion.* 4. Fresh portions of water pass through the bladder to supply the place of the water removed from its upper surface by *diffusion*, this operation being repeated so long as the process is sustained.

If a piece of *caoutchouc* or a film of *collodion* be substituted for the bladder the caoutchouc or collodion membrane will be *wetted* more easily by the *alcohol* than by the water; the *alcohol* will therefore be attracted more powerfully by the *capillary force* exercised by the membrane, and the action will be reversed; the alcohol, in this instance, passing outwards in place of the water's passing inward, as in the last experiment.

Professor Graham believes that the *liquid diffusion* has directly little or nothing to do with this process, and that it is dependent upon a series of alternate *hydrations* and *dehydrations* — that is, combinations with and deprivations of water, effected through the medium of the membrane, which, in all cases, undergoes more or less chemical action.

Endosmose (from Gr., *endon*, within, and *osmos*, impulse) is the term applied to that variety of *osmosis* in which the fluid passes *into* the vessel.

Exosmose (from Gr., *exo*, outside; *osmos*, impulse) is applied to that form of *osmosis* in which the fluid passes *out* of the containing vessel.

Liquid Diffusion.—If a tall glass jar be nearly filled with water, and a heavier solution be very care-

fully introduced into the bottom of the jar, so as not to disturb or mix the fluids, the heavier solution will gradually *diffuse* through the lighter one, and rise, *against gravity*, to the top of the jar, until at last the two liquids will be thoroughly mixed. This phenomenon is termed *liquid diffusion*. For its thorough investigation we are indebted to Professor Graham, who has shown that different liquids possess this power of *diffusibility* in very different degrees, but that the same body always possesses the same *diffusibility* under the same circumstances.

Crystalloids. — Professor Graham has divided bodies into two classes, according to their different degrees of *diffusibility*. Those bodies whose solutions diffuse with comparative rapidity, or which, in other words, possess a *high* degree of *diffusibility*, he has termed *crystalloids*. This class includes most of the crystallizable salts, the acids, and all the powerful *poisons*. The *crystalloids* are, in general, chemically active, sapid, and free from *viscosity*. Those bodies which are marked by a very *low* degree of diffusibility are designated *colloids*.

Colloids (from Gr., *kolla*, glue, and *eidos*, appearance), which are remarkable for their *low* diffusibility, are, in general, possessed only of a *low* degree of *chemical* activity, have a feeble taste, and a strong tendency to be *viscous* or *gelatinous*. They have also, in general, a *complex atomic structure*, and manifest a strong tendency to decomposition. The *colloids* include starch, dextrine, the vegetable gums, caramel (burnt sugar), tannin, gelatin, albumen, and animal and vegetable extractive matters, together with certain metallic oxides of little interest to the physiologist.

Dialysis (from Gr., *dia*, through, and *luo*, I loosen). —Professor Graham has shown that if a mixture consist-

ing of solutions of a *crystalloid* and a *colloid* be placed in a shallow vessel, having a paper, parchment, or membranous bottom, and this vessel be placed on a tripod or other stand in a basin containing pure water, so that its lower surface shall be in *contact* with the water, the *crystalloid* will pass *through* the membrane into the water contained in the external basin. In this way he has shown that it is quite easy to separate *poisonous* substances from the contents of the stomach and other digestive fluids. To this process of *analysis* by the action of *osmosis* he has applied the term *dialysis*. The instrument used he terms a *dialyser*. Professor Graham has proved the presence of free *hydrochloric* acid in *gastric* juice by this process of *dialysis*.

The Dialyser used by Professor Graham consists of a gutta-percha hoop, about six inches in diameter, and about two inches deep; over the *lower* end of this a piece of *paper*, *parchment*, or other suitable material is tied, care being taken to make the whole watertight. The liquid to be *dialysed* is poured into the *dialyser* to the depth of about half an inch. The *dialyser* is then *floated* in a glass basin containing from five to ten times its volume of water, and left for twenty-four hours, during which the poisonous *crystalloid*, or other substance, *dialyses* out by *osmosis*.

Osmotic Force.—Neutral *organic* substances and neutral salts are but feebly *osmotic*. Very dilute solutions of the *alkalies* and *alkaline carbonates* are powerfully *osmotic*. *Stronger* alkaline solutions are much *less* osmotic than *weaker* ones. This fact is exceedingly interesting in relation to the *blood* and *nutrition*, the serum of the *blood* being an exceedingly feeble alkaline solution. Common salt powerfully reduces *osmotic* action in other salts.

The *absorption* of the *peptone* from the stomach, of the *chyle* from the intestines by the lacteals, and the action of saline purgative medicines, have been attributed by physiologists to the action of *osmosis*.

Though *osmosis* is essentially a *physico-chemical* process, yet there can be but little doubt that in the study of its phenomena, to a great extent, rests the true future explanation of many of the most important and interesting physiological processes, including, among others, those of absorption, nutrition, secretion, and the *selective* power exercised by the tissues.

If the stem of the funnel described in the paragraph on osmosis be *graduated*, the amount of the *osmotic action* may be measured; the instrument is then termed an *osmometer*.

IMPORTANCE OF A KNOWLEDGE OF CHEMISTRY IN PHYSIOLOGY.

As probably many of our readers will not previously have been through a course of chemical study, it becomes necessary to explain with some accuracy what ideas are intended to be conveyed by the terms *acid* and *alkali*, so frequently used in describing the *digestive* juices. Without accurate ideas on these subjects no *really scientific* knowledge of the nature of digestion, and of many other physiological processes, is attainable. Professor Huxley, in a recent report on the Government Science Examinations in Physiology, strongly and justly complains of that pretentiousness to *physiological* knowledge, on the part of some candidates, which permits such gross perversions as the describing of the *gastric juice* as an *alkaline* fluid, and the bile as an *acid* fluid. It is quite clear that in such cases, which are unfortunately very

common, the student has adopted certain terms without realizing their true value. In the course of this little book we repeatedly go a little out of our way to give so much of chemical knowledge as is necessary to a *sound* and *real* explanation of the subject immediately treated of; but these explanations are in no instance intended to supply the place of a *systematic study of chemistry*, and the reader is again advised to join one of the numerous *Science* Classes established all through the country, by the aid of the Department of Science and Art, with the view of promoting the *national* study of science. There is but one mode of studying the physical sciences. No mere *verbal* description, whether by *book* or by the *living voice*, can supply the place of actual *observation* on the part of the student.

It is *absolutely* necessary, whether for the purpose of *mental training* or actual practical *utility*, that the student should know, by his own observation, the leading and distinctive *physical* and *chemical* properties of all ordinary bodies, together with the *phenomena* which result from these properties.

Acids are substances which are distinguished by certain well-marked and characteristic qualities. When soluble they have a *sour* taste, and *redden* vegetable *blues*. They have a powerful affinity or *chemical* attraction for a peculiar class of compounds termed *bases*, the majority of which consist of compounds of *oxygen* and a *metal*. This latter combining power is their most *general* and *distinctive* characteristic. When they enter into combination with these *bases* they *neutralize* them —that is, cause their peculiar properties to disappear for the time; their own peculiar properties also disappearing *simultaneously*. Some acids are insoluble in water, and therefore neither possess a sour taste nor

are capable of reddening the vegetable blues. Strong *vitriol* or *sulphuric* acid dropped on to a silk dress or a black coat will immediately produce *red* spots. These spots will soon fall into holes unless the acid be immediately neutralized. Solution of *ammonia* (or hartshorn) applied immediately will restore the colour, and delay the formation of the holes. The *ammonia* is a base, and it neutralizes the acid.

EXPERIMENT I. — Procure some strong vinegar. Observe it has an intensely *acid* or *sour* taste. Drop a little of it into a solution of *blue* litmus, and observe that it is immediately changed from a deep *blue* to a bright *red* colour. Procure a little of the common *carbonate of soda*, such as is used in "washing;" dissolve a little in water, and add it slowly to the *reddened* litmus solution. Observe that its bright *red* tint immediately *disappears*, and that its original *blue* colour is immediately *restored*. The *soda* (an *alkaline base*) of the carbonate of soda added has neutralized the *acid* properties of the vinegar, which consists of impure *acetic* acid. The colour of common *red ink* is due to the *acid* it contains. This *acid* quickly *corrodes* steel pens; from which circumstance it is always advisable to use quill pens in writing with *red* ink.

Litmus is obtained by digesting the *Rocella tinctorium* (one of the lichens), in a hot solution of carbonate of ammonia, when a very deep blue solution is obtained, which may be extracted by water.

EXPERIMENT II.—Place a common egg in a tumbler, and fill the remaining space in the tumbler with strong vinegar; in the course of a few days the egg-shell will have entirely disappeared. The vinegar (*acetic acid*) will have combined with the *earthy matter* of the shell, which is chiefly composed of *lime*, a *powerful base*, and the compound so formed will have

completely dissolved, leaving the egg shell-less, and completely exposing its lining membrane. A more powerful acid will effect this result with much greater rapidity.

Experiment III.—Drop a few drops of *sulphuric* or *hydrochloric* acid into a glass containing white of egg (*albumen*). The *acid* will immediately *coagulate* or solidify the *albumen* of the egg, forming a white, opaque, soft, solid substance, similar to that produced by boiling an egg.

Dr. Beaumont states that liquid *albumen* taken into the stomach is in like manner *coagulated* by the action of the *gastric juice*, but this is strongly denied by other physiologists.

The presence of a sufficient quantity of *free* (uncombined) *alkali* will prevent any of the results obtained in these experiments.

Acids at ordinary temperatures produce no change on *fatty* substances.

The Alkalies are exceedingly soluble bodies, possessing properties entirely unlike those of the acids. The chief *alkalies* are *potash*, *soda*, and *ammonia*. They have a strong, pungent, acrid, but when *dilute*, *soapy* taste; do not redden *blue* litmus, but *restore* the original *blue* of reddened litmus. They also turn *purple* cabbage water *green*, and change the *bright yellow* of turmeric (a yellow dye) to a decided *brown*. The alkalies *neutralize* acids, and enter in minute quantities into the composition of most organic compounds. Their most important property in a *physiological* point of view is their power of forming *soluble* compounds with *fatty* substances. When *oils* and *fats* are heated with *potash* or *soda*, they form certain chemical compounds termed *soaps*.

A familiar idea of the taste, general appearance, and

properties of an *alkali* may be derived from common domestic *washing soda*, which is an impure compound of the *alkali* (soda) and *carbonic acid*, the *acid* being too feeble to entirely neutralize the powerful *basic* properties of the *soda*.

Lime, magnesia, and some other similar bodies, in many respects *chemically* resemble *potash* and *soda*, but possess a very much lower degree of *alkalinity;* they have therefore been termed *alkaline earths.*

The *blood* is slightly *alkaline* from the presence of *soda.* The *bile*, the *pancreatic* and *intestinal* juices, are also more or less *alkaline*, hence their power of acting upon the *fatty* substances of the food during *intestinal* digestion.

EXPERIMENT.—Pour some oil into a bottle, and shake it up until its sides are well greased; pour off the remainder of the oil, and drain the bottle. Then introduce some pure water; well shake the bottle, and pour off the water. You will observe the interior of the bottle is still dirty, and that however frequently the operation be repeated, the bottle will remain *greasy.* The water cannot combine with oily matter, which in fact repels it, and therefore cannot cleanse the bottle. Again introduce water into the bottle, to which add a small quantity of an *alkali* (soda or ammonia). Again well shake the contents, which quickly combine, becoming white, opaque, and milky, and forming an *emulsion* very much resembling *chyle* in appearance. Pour off the contents, and again well wash. The bottle will now be found quite clean, and free from *grease.* The *oil* and the *alkali* have combined and produced a *soluble* compound, which is readily removed by washing.

The same *theory* explains the use of *soap* in washing the hands or the clothes. The person and the clothes

become covered with a more or less greasy exudation; this by its *repellent* power prevents the thorough contact of the water, which is thereby unable to exercise its cleansing power. Upon the application of the *soap*, the *alkali* which it contains combines with the grease on the hands or the clothes, and forms a *soluble* compound which is immediately dissolved; the water is thus brought into perfect contact with the surfaces to be cleansed, and enabled to exercise its detergent or cleansing power.

VOMITING, REGURGITATION, AND ERUCTATION.

Vomiting is the *abnormal* passage of the *food*, or other substances, from the stomach through the *œsophagus* back into the mouth. The exact nature of this process is still a subject of discussion among physiologists, who have not yet determined the precise part played by the stomach in this phenomenon. Some physiologists contend that the stomach is the *principal* agent in the act of vomiting, while others contend that it is entirely *passive*, the *expulsive* force being due, not to the *contractile* force exerted by the stomach, but to the *compression* produced by the powerful contraction of the *abdominal* muscles.

Magendie removed the stomach from a dog, and substituted a bladder for it. He then injected a solution of *tartar emetic* into its veins, which quickly produced copious vomiting, notwithstanding the substitution of the *bladder* for the stomach. This experiment proves that vomiting may be effected without the agency of the stomach, but it does not prove that this is usually the case. The probability is, that in most ordinary cases of vomiting both the walls of the stomach and the *muscular parietes* of the abdomen

concur in producing that result. The act of vomiting necessitates the following conditions:—1, the *pylorus*, or lower end of the stomach, must be tightly closed; 2, the upper end, or *cardiac* orifice, must be open, or but loosely closed; 3, the stomach must be *compressed*, either by its *own* muscular contractions, or by the action of the *abdominal* muscles.

The act of vomiting is most interesting in a physiological point of view, in consequence of the numerous organs concerned, and the *co-ordination* of function established in producing that result. The following stages are usually presented in the act:—1, a feeling of severe sickness or nausea prevails; 2, *retchings* occur, which probably *open* the *cardiac* orifice of the stomach; 3, the *respiration* becomes violently disturbed; the *diaphragm*, on descending, becomes spasmodically fixed; almost simultaneously the *glottis* also becomes violently closed, the chest being full of air; the diaphragm is thus fixed by its own contraction and the pressure of the enclosed air; 4, at the same time the *abdominal* and other muscles contract violently on the stomach, which, probably aided by the muscular contraction of its walls, expels its contents with great violence, not unfrequently overcoming the resistance offered by the soft palate, and driving the expelled substances through the nose; 5, the sudden and violent contraction of so many muscles, together with the violent fixing of the inflated chest, propels so large a quantity of blood into the vessels of the head and face as to produce temporary *congestion*. This *congestion* is sometimes so excessive as to cause death by *apoplexy*, or the bursting of the smaller vessels of the brain. In ordinary cases it shows itself by the *red* and *swollen* state of the features, and the *distension* of the veins of the neck and forehead.

Some writers contend that vomiting is produced by *antiperistalsis*, or the reversed *peristaltic* action of the stomach and duodenum. Vomiting is caused by *reflex* action (see "The Nervous System"), which may be excited by either of the *three* following *causes:*— 1, by the action of *irritating* substances on the *mucous* membrane of the *stomach:* in this instance the nerves of the stomach convey the impression they receive to the *medulla oblongata*, which returns the *motor* influence to the various muscles of respiration, the walls of the abdomen, the stomach, and adjacent organs, by the *nervous circle*, thus constituting the process a true phenomenon of *reflex* action; 2, by *irritation* applied to other parts of the body, as the injection of *tartar emetic* into the blood, the presence of morbid poison in the blood, the application of *wet tobacco* leaves to the armpits, the passage of a *renal calculus*, and irritation at the base of the *brain*, which also acting through the *nervous circle*, set up powerful *reflex* action; 3, by *sensational* or *emotional* impressions which only act through our *consciousness*, as the sight, smell, or recollection of a *disgusting* object, the tickling of the *fauces* at the back of the throat with a feather, sea-sickness, &c.

In all these cases the *medulla oblongata* (see "Nervous System"), and the *vagus* nerves (*pneumogastric*) passing from it, are affected, causing it to send out *motor* influences through their numerous branches to the *muscles* of the larynx, œsophagus, abdomen, chest, and to the diaphragm, and the muscular fibres of the stomach; thus co-ordinating their various actions to the production of one complex result. Vomiting is ushered in by a deep *inspiration*, immediately followed by an abortive attempt at *expiration*, checked by a more or less complete *spasmodic* closure of the *glottis*. Simul-

taneously the abdominal muscles contract powerfully, closing down upon the sides of the stomach, and compressing it violently between the walls of the abdomen and the under surface of the diaphragm, now fixed and rigid by its own contractions and the downward pressure of the air imprisoned in the chest. The contents of the stomach are thus expelled with considerable force.

The student who has carefully followed the explanation of this process will find in it an instructive illustration of the *parts* played by the various *tissues* which enter into the structure of the *organs* concerned in it. (See " Muscular and Nervous Tissue.")

Regurgitation (from L., *re*, again, and *gurges*, a whirlpool) is the process by which *fluids* are passed from the stomach back into the mouth. It occurs in *true* vomiting, but is usually a much less *complex* process.

In some cases the liquid is forced from the stomach up the œsophagus without producing any sensation, the person being quite unconscious of the act until he is made aware of it by the *taste* occasioned by the presence of the fluid at the back of the mouth. Such instances are quite unlike those of true vomiting, since they are not attended by any *respiratory* disturbances, the action being most probably of a merely local and physical character. In all probability they are, in general, merely accidental occurrences, the fluid being forced up by the air escaping from the stomach through the *œsophagus*. Or it may be forced up the *œsophagus* by the ordinary *peristaltic* contractions of the stomach, at the moment the cardiac orifice may be opened by the escape of the confined gases.

Eructation (from L., *eructo*, I belch) is the process by which the *gaseous* contents of the stomach are expelled through the mouth. It is in all probability due to the *expansive* force of the air which, being *secreted*

and collecting in large quantities in the stomach, forces open the *sphincter* muscle of the *cardiac* orifice, and escapes through the *œsophagus.* From its greater lightness the air would tend to collect in the upper or cardiac region of the stomach. Its expulsion is probably aided by the contractile force of the stomach. The air, sometimes escaping in large bubbles, carries up with it a portion of the liquid and solid contents of the stomach.

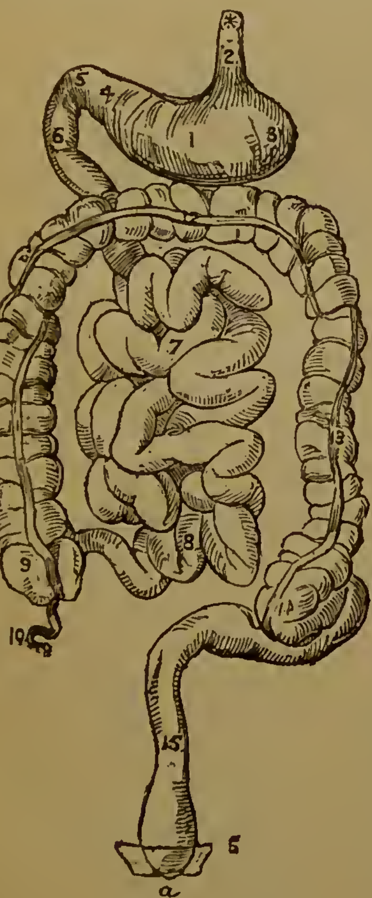
INTESTINAL DIGESTION, AND THE LARGE AND SMALL INTESTINES.

Intestinal Digestion.—The *chyme,* or partially digested food, leaves the stomach by the *pylorus* and enters the *intestines.* It there meets with certain *fluids* secreted by the *intestinal mucous* membrane, the *liver,* and the *pancreas,* by the action of which the process of digestion is completed. This part of the process is designated intestinal digestion, or *chylification.*

General Outline of Intestinal Digestion.—1, The *chyme* on leaving the stomach enters the *duodenum,* or first portion of the small intestines, in a decidedly *acid* state; 2, in the *duodenum* it meets with certain *alkaline* fluids, consisting chiefly of the *bile,* and the *pancreatic* and *intestinal* juices, by which its *acid* properties are *neutralized,* and its *fatty* portions converted into a kind of *emulsion,* by which they are rendered partially *soluble,* and fitted for *absorption* by the *lacteals* in the form of *chyle.* The conversion of the *starchy* portions of the food into *sugar* is also completed; 3, the contents of the intestines are pushed slowly onwards by the *peristaltic* movement of their walls; 4, the *chyle* and other *nutritious* substances are gradually removed from the intestines by *absorption* through the *lacteals* and the *veins* during the onward

passage of the aliment; 5, the indigestible and useless portions of the food, mixed with more or less of the *bile*, *intestinal juices*, and *mucus*, having arrived at the extremity of the *rectum*, or terminal intestine, by the action of *peristalsis*, are expelled from the system by the act of *defecation*, the *nutritious* elements of the food having, in healthy digestion, been previously removed by *absorption*.

11. Ascending colon.



2. Lower end of œsophagus.
1. Stomach.
3. Left end of stomach.
4. Right end of stomach.
5. Pylorus.
6. Duodenum.

12. Transverse colon.

7. Convolutions of jejunum.

13. Descending colon.

8. Convolutions of ileum.
9. Cæcum.

10. Its vermiform appendix.
14. Sigmoid flexure.

15. Rectum.

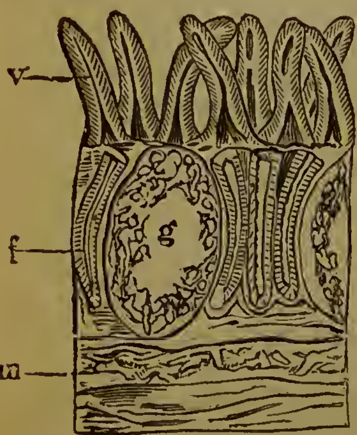
S. Sphincter.
a. Anus.

Fig. 14.—Alimentary Canal.
Showing lower end of œsophagus, stomach, and large and small intestines.

General Outline of the Large and Small Intestines.—The bowels or intestines, which are contained in the cavity of the *abdomen*, consist of a *tubular* continuation of the *alimentary canal.* (See Figs. 8, 14, and 15.) They are comparatively *short* in *carnivorous* or flesh-eating animals, but *long* in *herbivorous* or vegetable-feeding animals. In man and the monkey tribes, which are *omnivorous* (live on a *mixed* diet of animal and vegetable substances), they are of intermediate length.

In the human being they are about five times the length of the body. They are divided into *large* and *small* intestines. The *small* intestines, which are connected with the *pyloric* end of the stomach, are about 20 feet long and $1\frac{1}{4}$ inches in diameter. They form about 5-6ths of the entire length of the intestines. The *large* intestines are about 5 feet long, and 2 to 3 inches in diameter; they are connected with the end of the *small* intestines, which opens into the former by a *valve* of peculiar construction. The intestines, like the stomach, consist of four coats,—an external *serous*,

Fig. 15.—Vertical Section of Coats of Small Intestine.



Showing mucous coat, with—

v. *Villi* (greatly exaggerated).
f. *Lieburkühn's follicles*, resting on sub-mucous membrane.
g. *Lenticular* (Peyer's) *glands*, with their lower ends embedded in the sub-mucous membrane.
m. *Muscular coat*, showing inner transverse, and outer longitudinal layers of muscular fibre.

The outer *serous coat* has been dissected off.

a middle or *muscular*, an *areolar* or *sub-mucous*, and an inner or *mucous* coat. The *small* intestines are divided into three portions—the *duodenum*, the *jejunum*, and the *ileum*. The *large* intestines are also divided into three portions; viz., *colon*, *cæcum*, and *rectum*.

They are abundantly supplied with nerves, arteries, veins, and *lymphatics*, or absorbents. The intestines are surrounded by a *serous* membrane termed the *peritoneum*. The *small* intestines are completely *inclosed* by a portion of this membrane, termed the *mesentery*, which is attached to the *vertebral column*, and helps to retain them in their proper place. Large quantities of *adipose tissue*, or fat, which serves the double purpose of safely packing the intestines and protecting them from *cold* and *injury*, are distributed in different parts of the abdominal cavity. This *fat* sometimes increases in quantity to such an extent as to produce great inconvenience, as in extreme corpulence, where, by its pressure on the adjacent organs, it seriously interrupts the circulation, producing a partial *strangulation*.

The *inner* surface of the *small* intestines is nearly covered with minute threadlike processes termed *villi;* it is also studded with numerous *glands*, viz., the *duodenal* glands, or the *glands of Brunn;* the *intestinal tubuli*, or *follicles of Lieburkühn;* and the *lenticular glands*, which are generally distributed in clusters termed *Peyer's patches*. (See Figs. 15 and 16).

The *large* intestines are quite smooth, being destitute of villi; but their *inner* surface is studded with *intestinal follicles* and *solitary glands*. The *small* intestines are gathered into folds or *convolutions* by the *mesentery*, and the *large* intestines into *saccules* or pouches by the longitudinal muscular bands attached to their outer walls. The intestines possess three apertures or openings—the *pyloric* aperture, by which the *chyme* enters;

a *lateral* orifice in the *duodenum*, by which the *bile* and *pancreatic* juice enter; and a terminal aperture—the *anus*, at the lower extremity of the *rectum*, by which the *fæces*, or undigested food, &c., are expelled. The latter extremity is surrounded by a *circular* ring of muscle termed the *sphincter ani*, which, by its *continuous contraction* under the influence of the *spinal cord*, closes the terminal aperture of the canal, and, under *ordinary* circumstances, prevents the escape of the fæces without the permission of the *will*.

The Cavity of the Abdomen, which is the largest cavity in the body, occupies the lower region of the *trunk*. It is bounded *above* by the *diaphragm*, which forms its *roof;* at its base by the *pelvis;* in *front* and at its sides by the *lower ribs* and abdominal muscles and tendons; and *behind* by the *vertebral* column and the posterior abdominal muscles. It contains the principal organs of digestion, nutrition, and excretion, including the *stomach*, large and small *intestines*, the *liver*, *pancreas*, *spleen*, *kidneys*, and *bladder;* also segments of the trunks of *aorta* and the *vena cava*, which traverse it perpendicularly. (See Fig. 8.) It is lined internally by a *serous* membrane termed the *peritoneum*. The inner surface of the muscles forming the walls of the abdomen is also lined by a layer of *fasciæ*. The interior organs are retained in their places chiefly by the pressure of the abdominal muscles and their broad tendons. In cases of excessive muscular exertion, as in wrestling, and lifting heavy weights, it sometimes happens that the walls of the abdomen give way, and a portion of the bowel is extruded or forced out of its natural cavity. This constitutes *hernia* or rupture. Wrestlers, and those accustomed to labour requiring the excessive exertion of the abdominal muscles, frequently wear tight or

elastic belts, to strengthen the abdominal walls and enable them to resist this dangerous tendency.

Regions of the Abdomen.—Writers on anatomy divide the abdomen into nine *regions* for general convenience of reference and description, viz.:—

Right Hypochondriac, containing Right lobe of liver, gall-bladder, duodenum, hepatic bend of colon, upper part of *right* kidney, and supra-renal capsule.	**Epigastric Region,** containing Middle and pyloric end of stomach, *left* lobe of liver and lobus Spigelii, and pancreas.	**Left Hypochondriac,** containing Splenic end of stomach, spleen end of pancreas, splenic bend of colon, upper half of left kidney, and supra-renal capsule.
Right Lumbar, containing Ascending colon, lower part of right kidney, and portion of small intestines.	**Umbilical Region,** containing Transverse colon, part of great omentum and mesentery, part of duodenum, and portions of jejunum and ileum.	**Left Lumbar,** containing Descending colon, lower part of left kidney, and portion of small intestines.
Right Inguinal, containing Cæcum, vermiform appendix, and ureter.	**Hypogastric Region,** containing Portion of small intestines and bladder.	**Left Inguinal,** containing Sigmoid flexure of colon, and ureter.

The *upper zone* lies immediately below the *true* ribs; the *middle zone* includes the *central* portions of the abdomen; and the *lower zone* passes across the *hips* and *groins*. If two circular parallel lines be drawn through the body—the one touching the cartilages of the ninth

ribs; the other passing over the highest points to the *iliac*, or hip bones—they will divide the abdomen into the zones described.

The *central* region of the upper zone lies over the stomach, and is therefore termed the *epigastric* region (from Gr., *epi*, upon, and *gaster*, the stomach); the two lateral regions lie under the costal (rib) cartilages, and are therefore termed *hypochondriac* regions (from Gr., *hupo*, under, and *chondros*, cartilage).

The *central* region of the middle zone lies over the centre of the abdomen, and is termed the *umbilical* region (from L., *umbilicus*, navel); its two lateral regions lie over the loins, and are therefore termed the *lumbar* regions (from L., *lumbus*, loin).

The *central* region of the lower zone is termed the *hypogastric* region (from Gr., *hupo*, under, and *gaster*, the stomach); its two lateral regions lie over the groins, and are therefore termed the *inguinal* regions (from L., *inguen*, groin).

The Peritoneum (from Gr., *peri*, about, and *teino*, I stretch) is a *serous* membrane which lines the entire cavity of the abdomen, and is *reflected* over the various organs contained in it, so as to furnish them with a more or less complete *external* covering in addition to their own *proper* coats. It consists of an inner layer of scaly or *squamous epithelium*, resting on *basement* membrane, supported by a thick layer of condensed *areolar tissue*, which forms the bulk of its substance.

Its inner or *free* surface is smooth, and is moistened by a small quantity of *serous fluid*, which *lubricates* it and lessens its *friction* with the surfaces of the adjacent organs. When this fluid is secreted in *morbid* quantities it accumulates in the abdomen, constituting the disease termed *ascites* (from Gr., *askos*, a leathern bottle), or

dropsy in the abdomen. Its *attached* surface is rough, being formed of loose sub-peritoneal areolar tissue. The *parietal* portion is loosely attached to the *fasciæ* of the muscles forming the inner walls of the abdomen, and still more loosely to the *diaphragm*. It gives off three *broad* processes termed *omenta* (from L., *omentum*, the caul), viz. :—the *lesser* or *gastro-hepatic omentum*, which extends between the *liver* and the upper part of the *stomach*; the *great* or *gastro-colic omentum*, consisting of four broad folds, which descends from the stomach, forming a layer in front of the small intestines, and also partially enclosing the colon; and the *gastro-splenic omentum*, which connects the concave surface of the *spleen* with the large end of the *stomach*.

The *great omentum*, during health, always contains fat, which protects the intestines from the cold, and tends to facilitate their movements on each other during their *peristalsis*.

Other *processes* of the peritoneum which serve to support the liver, spleen, bladder, &c., are termed *ligaments* (from L., *ligo*, I bind).

The Mesentery (from Gr., *mesos*, middle, and *enteron*, an intestine) is that portion of the *peritoneum* which *encloses* the small intestines and attaches them to the spine. Its *root*, which is attached to the *vertebral column*, is about six inches long; while its intestinal border, only four inches from the *root*, is about twenty feet long. The gathering of the small intestines into *convolutions* is due to this arrangement.

The folds of the peritoneum which enclose portions of the *cæcum*, *colon*, and *rectum*, are respectively termed the *meso-cæcum*, *meso-colon*, and *meso-rectum*. Certain small pouches of the *peritoneum* filled with fat are termed *appendices epiploicæ* (from Gr., *epi*, upon, and *pleo*, I float). Inflammation of this membrane is termed

peritonitis; it sometimes causes the adjacent walls to adhere, and thus interferes with the movements of respiration and digestion.

The Pylorus (from Gr., *pulorus*, a gatekeeper), a gateway by which the *chyme* leaves the stomach. (See 9, Fig. 7), was formerly regarded as a *valve*, endowed with a peculiar sensibility by which it distinguished the *chyme*, or partially digested food, and permitted it to pass, refusing permission to the passage of other substances until *wearied* out. But modern physiologists describe it as a sort of *filter* or *strainer*, through the *minute central* aperture in which the more fluid and homogeneous portions of the food or other substances are pressed by the *mechanical* contractions of the stomach. When the stomach is nearly empty the pyloric contraction ceases, and the undigested food and other bodies, as marbles, coins, &c., pass into the intestine.

The *pylorus* consists of an inflection or *reduplication* of the muscular coat and *mucous* membrane, which form a kind of ring or circular fold at the small end of the stomach. The *mucous* fold is surrounded by a thick layer of transverse *circular* muscular fibre, which also contains a few *longitudinal* fibres, and is derived from the ordinary *muscular* layer of the stomach. This sudden thickening of the *transverse muscular* coat forms a kind of *sphincter* muscle, which is sometimes described as the *pyloric sphincter*.

The Duodenum (from L., *duodeni*, twelve), or first portion of the small intestine, commences at the *pylorus* and terminates at the *jejunum*. (See Figs. 7 and 14.) It is about twelve finger-breadths, or ten inches in length, and forms the widest and broadest portion of the *small* intestines. It forms a curve, somewhat like that of a horseshoe, the concavity of which receives the right end of the pancreas; and has an *ascending*, *trans-*

verse, and *descending* portion. It has no *mesentery*, and is only partially covered by the *peritoneum*. The common *bile* duct, and the *pancreatic* duct, *perforate* the descending portion very *obliquely* a little below the middle. Its inner surface is covered by *mucous* membrane, containing *Brunner's glands*, which are very numerous in its upper part, *Lieberkühn's follicles*, *villi*, which are very numerous in its lower two-thirds, *solitary* glands, in its lowest third, and *valvulæ conniventes*, which are well developed in its inferior half. The *chyme* here becomes mixed with the *bile* and *pancreatic juice*, discharged through the orifice just described. The first or ascending portion of the duodenum is usually found, after death, stained with *bile*.

The Jejunum (from L., *jejunus*, empty) is the second portion of the small intestine; it derives its name from the circumstance that it is usually found *empty* in the dead body. (See 7, Fig. 14.) It forms the upper 2-5ths of the *small* intestines *from below* the *duodenum*, with which it is connected. It commences at the *duodenum* and terminates at the *ileum*. It possesses no *special* characteristics by which it may be *absolutely* distinguished from other portions of the small intestines; the division made by physiologists, though convenient, is therefore mainly an *artificial* one. The *jejunum* is a little larger than the *ileum*, its coats are a little thicker, and its colour a little deeper. It is well studded with *Lieberkühn's follicles*, *villi*, and *solitary glands*. Its *valvulæ conniventes* are also larger and better developed than those of any other portion of the intestines. It chiefly occupies the *umbilical* and *left iliac* regions of the abdomen.

The Ileum (from Gr., *eileo*, I twist) forms the third, terminal, and narrowest portion of the *small* intestine; it terminates in the *cæcum*, the aperture

being guarded by the *ilio-cæcal* valve. (See 8, Fig. 14.) It is studded with *crypts of Lieberkühn*, *solitary glands*, and well-developed *villi*, which are, however, less numerous than in other parts of the small intestine. The *valvulæ conniventes* gradually diminish in numbers, and ultimately disappear towards the end of the *ileum*. It is also less *vascular* than the *jejunum*. It occupies the *umbilical*, *hypogastric*, *right iliac*, and occasionally the *pelvic* regions of the abdomen.

The Intestinal Villi (from L., *villus*, a hair) consist of slender *papillæ*, or short, thread-like *processes*, which are attached *vertically* to the inner wall of the alimentary tube (see Figs. 15 and 16). They are formed

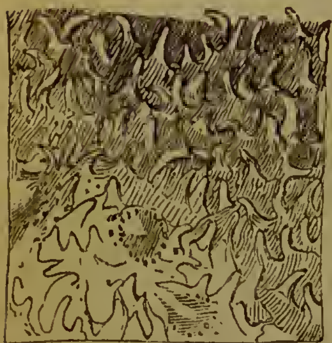


Fig. 16.—Inner Surface of Intestine (Ileum).

Showing mouths of *Follicles*; *Peyer's glands* surrounded by mouths of *Follicles*; and *villi*.

by extensions of the surface of the *mucous* membrane of the small intestines, and give it a soft, yielding, fibrous, *velvety* appearance. The *villi* are most numerous in the *duodenum* and the upper part of the *jejunum*, where they are so close as nearly to cover the inner wall of the intestine, their number here being estimated at from fifty to ninety to the square line; but they are much less numerous towards the end of the *jejunum* and the *ileum*. They are spread over the whole surface of the small intestines up to the *ileo-cæcal* valve. It has been estimated their total number

exceeds 4,000,000. Dr. Brinton suggests that their form, situation, and function entitle them to be termed the *intestinal* or *chyliferous papillæ.*

Structure of a Villus.—Each *villus* is of a somewhat flat and triangular shape, and is about 1-30th to 1-12th of an inch long; its breadth is about 1-5th, and its thickness about 1-10th, of its height. It consists *externally* of a covering of *columnar* epithelium, attached to a lining of *basement* membrane. The

Fig. 17.—A VILLUS.

Diagram exhibiting the structure of a villus.

A. Outer layer of columnar epithelium.
B. A single cell.
C. Basement membrane.
D. Capillary plexus.
E. Commencement of a lacteal.

interior of the *villus* contains a *network* of *capillary* vessels, and a central *lacteal*, which are supported by a *granular matrix.* Some physiologists describe a delicate *muscular* coat or *tunic* as surrounding the *lacteal* in the middle of the villus. (See Fig. 17.)

The Lacteals (from L., *lac*, milk), in the *centres* of the *villi* (Fig. 17, E), most probably consist of single *club*-shaped tubes of structureless basement membrane. Some writers have described each central lacteal as ori-

ginating in a microscopic network of vessels; but this appearance is attributed by other writers to *optical* illusion. The diameter of the *central lacteal* is about 1-6th of that of the villus. These lacteals are supposed to absorb the *chyle* by the action of *endosmosis*. They are much expanded about five hours after a meal, being full of a white opaque fluid, the chyle; at most other times they are empty, and almost invisible. (See Fig. 20.)

The Muscular Tunic, which is described as surrounding the *central lacteal*, consists of *organic muscular fibre*. It lies between the central *lacteal* and the *capillary* vessels of the villus. It is supposed to aid, by its contractions, the propulsion of the chyle through the vessels.

The Capillary Networks of the *villi* consist of capillaries about 1-3000th of an inch in diameter. Each *plexus* is derived from a minute artery (see Fig. 18), about 1-1000th of an inch in diameter, which enters the *base* of the *villus* and immediately divides,

Fig. 18.—Capillary Plexus of a Villus.
Highly magnified, showing—
A. Artery, which breaks up and forms the capillary network.
V. Vein, formed by the junction of the *venous* capillaries. (The veins and *venous* capillaries are shown by the shaded portions of the diagram.)

giving off the branches which compose the network described. Their meshes are exceedingly close; their length is about five times their width. These capillaries are exceedingly *tortuous*. The *veins* commence at the termination of the arteries in the *upper* part of the *villi*, and run into each other as they pass down the *lacteal*, ultimately uniting into a single vein, which passes out at the *base* of the *villus*.

The Valvulæ Conniventes, or *valves of Kerking*, are *transverse permanent* folds or valves of the *mucous* membrane, which project into the cavity of the bowel. (See 10 to 14, Fig. 7.) They form *arcs* about 2 inches long, extending 3-4ths or 5-6ths round the canal, the largest of them being about 3 to 6 lines deep at the middle of the arc, and gradually diminishing in depth towards their extremities, where they sink into the general surface of the *mucous* membrane. Each *valvule* consists of a fold or *reduplication* of the *mucous* membrane and *sub-mucous areolar tissue*, with its nerves, capillaries, and lacteals. It therefore comprises a double layer of *basement* membrane and *epithelium*, and an *intermediate* layer, consisting of *areolar* tissue, *lacteals*, *nerves*, and *capillaries*. Their surface is studded with *villi* and Lieberkühn's follicles. When the intestine is greatly distended, the *valvulæ conniventes* become erect, standing perpendicularly from its sides. They are distributed through the small intestines, but are most numerous in the *jejunum*, where they attain their *maximum*, gradually diminishing again until they disappear at the end of the *ileum*.

Their apparent *functions* are,—1, to increase the *absorptive* surface of the *mucous* membrane, whose area they double or treble; 2, to *retard* the *passage* of the food along the intestine, and thus promote the more complete *absorption* of its *nutriment*. They probably

derive their name from their pretendedly obstructing, but really *conniving* (from L., *con*, together, and *niveo*, I wink) at the passage of the intestinal contents.

The Intestinal Tubuli, or Crypts, or Follicles of Lieberkühn, very closely resemble the *gastric follicles* or *tubuli* already described. They probably secrete the proper *intestinal* juice. They are so numerous in man that it has been estimated they *increase* the surface of the *mucous* membrane of the intestines to ten and fifteen times the mere surface of the tube. They are more numerous in the *large* than in the *small* intestines. (See Figs. 15 and 16.) They consist of minute tubular prolongations of the *mucous* membrane, arranged perpendicularly. Each tube forms a hollow cylinder, closed at its base but open on the *free* surface of the membrane, its length being about five times its diameter. The interior of the tube consists of a single layer of *columnar epithelium*, which lines its minute *bore* or *cavity;* behind this is a layer of basement membrane, which supports the *epithelium*, and is surrounded by a *plexus* of capillaries; the whole being supported by a *matrix* of sub-mucous areolar tissue. (See "Gastric Follicles," and "Capillaries.")

The Duodenal Glands, or Glands of Brunn, are small *racemose* (grape-like) glands which are embedded in the sub-mucous areolar tissue. (See Fig. 19). The largest are about 1 to $1\frac{1}{2}$ lines in dia-

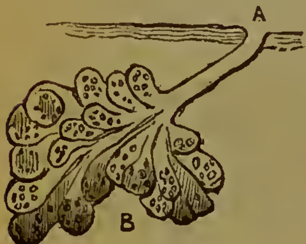


Fig. 19.—BRUNNER'S GLAND.

Showing A. *Duct* opening on the surface of the *mucous* membrane.

B. Racemose (grape-like) gland.

meter, they open into the *duodenum* by a minute *duct.* Their structure very closely resembles that of the *elementary lobules* of the *salivary* glands and the *pancreas*, consisting of clusters of *acini*, or grape-like vessels, 1-300th of an inch in diameter, lined by *tesselated epithelium*, and connected together by minute branches of the *efferent duct;* the whole, in its general arrangement, closely resembling a bunch of grapes. One of these *duodenal* glands would correspond to an *elementary lobule* of one of the *salivary* glands. They are invested by a delicate layer of *areolar* tissue, and are sometimes described as *conglobate* glands. (See "Pancreas," and "Salivary Glands.") They *secrete* a viscid, structureless, alkaline *mucus*, which is capable of converting *starch* into *sugar.*

The *duodenal* glands are very numerous in the upper part of the tube, near the *pylorus*, where they have been described as *salivary* glands spread out on a *large surface* instead of being collected into a *mass.* In the lower part of the tube they are smaller, and are sparsely scattered; they are almost entirely confined to the *duodenum* and commencement of the *jejunum.*

The Lenticular, Solitary, and Agminated Glands.—These glands are closed *capsular glands*, comprising a *capsule* and *semifluid* contents. (See Fig. 15, *g*, and Fig. 16.) They are found both in the stomach and intestines, but more abundantly in the latter. They form small *follicles* or *closed sacs*, of a *rounded* or slightly *conical* shape, the flatter end or *base* of which rests on the *muscular* coat of the *stomach* or *intestine*, their conical end or *apex* being turned towards and *projecting* slightly into the interior of the intestines. Their diameter varies from 1-5th to 3-5ths of an inch. The *capsule* consists of an outer coat somewhat resembling *basement* membrane, but thicker and indistinctly

fibrous, and penetrated by minute *capillaries*, which *ramify* on its surface. The *contents* of the *follicle* consist of a pale, greyish, opalescent, semifluid substance, containing a mixture of *fluid* and *cells.*

In general they have no duct or opening; but in the *large* intestines especially they very frequently have a minute orifice, as if the *capsule* had *burst* at its *apex*, and discharged its contents into the intestine.

The *function* of these *follicles* is unknown. Some writers suppose them to be allied to the *lymphatic* system, while others suppose them to be related to the small lentil-shaped *salivary* and *mucous* glands of the *tongue* and *tonsils.*

These glands have been termed *lenticular* (from L., *lens*, a lentil), because of their being *convex* or *lens*-shaped. When existing singly they are called *solitary glands;* when occurring in *clusters* they are termed *agminated glands* (from Gr., *agmen*, a group or cluster). These *clusters* are also termed *Peyer's patches.*

The Cæcum (from L., *cæcus*, blind), or blind gut, is the large blind or closed sac or pouch which forms the commencement of the large intestine. (See 9, Fig. 14.) It is about 2½ to 3 inches in diameter, and about the same in length. It forms a sort of *cul-de-sac*, making an acute angle with the *ileum*, which opens into it. It is situated in the *right iliac fossa* (cavity), being bound down to the *fasciæ* of the muscles of the front wall of that region by the *peritoneum* and *areolar tissue;* it is comparatively immoveable, and therefore, by its contraction or distension, displaces the neighbouring portions of the small intestine. It is sometimes invested in a complete fold of the *peritoneum*, termed the *meso-cæcum* (from Gr., *mesos*, middle). Its walls are *puckered* into small pouches, cells, or *sacculi*, which are arranged in three

vertical rows separated by ridges. This structure is due to the peculiar arrangement of the *outer* muscular layer, and prevails through the whole of the large intestine, except the *rectum*.

It has three apertures—a nominal aperture at its commencement, where it joins the *colon;* a second aperture at its upper, posterior, and left side, which communicates with the *ileum;* and a third opening which communicates with the *vermiform appendix*. The *cæcum* forms the *widest* portion of the alimentary canal, excepting the stomach. It is in this portion of the intestine that the food begins to acquire the peculiar odour and properties of the *fæces*.

The Vermiform Appendix (from L., *vermis*, a worm) is a small, closed, narrow, *worm*-shaped tube, two to six inches long, and about the diameter of an ordinary goosequill. It opens into the back of the base of the *cæcum*, nearly under the *ileo-cæcal* valve, the orifice being furnished with an imperfect valve or fold. The structure of its walls resembles that of the rest of the *large* intestines. Its *mucous* coat is studded with *solitary* glands, and moistened with a thick glairy *mucus*. It is sometimes described as a *rudimentary* continuation of the *cæcum*. Its function is unknown. Only man, the orang-outangs, and the gibbons, possess this appendage. Dr. Brinton states that the *cæcum* acts chiefly as a receptacle in which the matters received from the small intestine sojourn awhile before entering the colon. It is very large in the *herbivora*, but small in the *carnivora*.

The Ileo-cæcal Valve, which guards the entrance of the *ileum*, and prevents the return or *regurgitation* of the contents of the *colon* and *cæcum*, consists of two *valvular folds* of *mucous* membrane. The *ileum* opens into one of the constrictions or projections on

the left side of the *cæcum* and *colon* by a horizontal, flattened, or *slitlike* aperture; its upper lip being connected with the *colon*, and its lower lip with the *cæcum*. The *mucous* membrane of the upper lip forms a *semilunar* fold or valve, the *ileo-colic* projecting into the colon. The *mucous* membrane of the lower side of the *ileum* forms a similar but larger valve, the *ileo-cæcal*, which projects into the *cæcum*. The lips of these laminæ or folds meet, inclosing a nearly horizontal *slitlike* aperture, their ends being joined into *frænæ* (from L., *frænum*, a bridle), or membranous folds. When a substance passes from the flattened end of the *ileum* into the *cæcum* it pushes these lips asunder, and readily enters the cavity of the *cæcum* by the intermediate *slitlike* aperture. But when the pressure acts in the opposite direction, through *distension* of the *cæcum*, or the attempted *reflux* of its contents into the *ileum*, these valvular folds are brought into *apposition*, and pushed tightly together, so that the intervening *slitlike* orifice is violently closed, and the backward passage of the substances is prevented. The mucous membrane composing these folds includes *circular* and *longitudinal* muscular fibre. The surface of the folds directed towards the *ileum* is covered with *villi* corresponding with those of the *ileum;* but the surface directed towards the *large intestine* is, like the rest of its internal wall, entirely devoid of *villi*.

The Colon (from Gr., *koilos*, hollow) is the *second* and longest portion of the *large* intestines. (See Fig. 14.) It is connected with the *cæcum*, commencing at the upper margin of the *ileum* and terminating at the *rectum*. It is divided into four portions or segments—an *ascending*, *transverse*, and *descending* portion, and the *sigmoid* flexure. Its sides are *sacculated* like those of the *cæcum*. During its *peristaltic* action these *sacculi*

alternately dilate and contract by the action of the *circular muscular fibre.* The *longitudinal fibres* also promote the action of these *sacculi* by alternately contracting and elongating, and thus widening and shortening a series of them. The contents of the *colon* are forced up the ascending colon, from one series of *sacculi* into another, *against gravity.* The former practice of tight lacing, now, happily, very generally abandoned by English ladies, not only most seriously impaired the *peristaltic* action of this as well as other intestines, but very frequently drove it permanently out of its natural position.

The *colon* commences at the *cæcum* in the *right iliac* (hip) fossa ; it then, ascending to the under surface of the liver, bends at right angles, and *crosses* horizontally (*transversely*) below the stomach, after which it bends down under the *spleen*, and descends nearly vertically towards the *left iliac* (hip) fossa ; here it makes a peculiar double curve very much resembling the letter **S**, forming the *sigmoid flexure* (from Gr., *sigma*, the letter S). It then passes obliquely down towards the median line, and terminates in the *rectum.*

The walls of the *colon* and *cæcum* are smooth, and entirely destitute of *villi* and of the *valvulæ conniventes;* but they are indented with rows of *sacculi*, which are separated by constrictions or *ridges.*

The Rectum (from L., *rectus*, straight), or *straight gut*, commences at the *colon*, and extends to the *anus*, or terminal aperture of the *alimentary canal.* (See Fig. 14.) It is six to eight inches long. Its interior is smooth, cylindrical, and *not sacculated*, like the rest of the large intestines. It is smaller above, increasing in size down to the *anus*, immediately above which it is largest, and admits of very great *dilatation.*

Its *lower* end is supplied with an *internal* and an

external ring of muscle termed respectively the *external* and *internal sphincter muscles*, the relaxation of which opens the *anus* and discharges the *fæces*. These muscles are maintained in a state of permanent contraction by the influence of the *spinal cord*. During *panic*, *paralysis*, some forms of *insanity* and *cerebral* disease, this influence is sometimes withheld, producing the *involuntary* discharge of the fæces.

The lower end of the *rectum*, which is not invested by the *peritoneum*, is partly supported by the *levator ani* (from L., *levo*, I lift up) *muscles*, which assist in the act of defecation.

The *mucous* membrane of the *rectum* is looser than that of the colon, and collects into temporary folds, principally *longitudinal*. In addition to these, the *rectum* is supplied with three and sometimes four permanent valves, flaps, or *septa*, which act like "shelves to pack the *fæces* on," and prevent the entire weight of the contents of the *rectum* bearing on the *anus*.

Peristaltic Movement of the Intestines (from Gr., *peri*, about, and *stello*, I send).—The contents of the intestines are gradually urged onwards by the *peristaltic* action of its *muscular* walls. This process is compounded of the following movements :—

1. A portion of the *circular* muscular fibres of the intestines contract, by which a *ring* or transverse *constriction* is produced, and its circumference and internal area are greatly diminished; portions of the intestinal contents are propelled by this contraction into the part of the tube *next below* it, moving downwards towards the rectum, or termination of the intestines.

2. The portion of the intestinal tube *next below* the *ring* or transverse *constriction*, having received the substance driven from above, now commences the same process of *constriction*, the first portion of

the tube still retaining its *contracted* state, and propels a portion of its contents into the segment of the intestinal canal *next below* it.

3. The first segment of the tube now *relaxes*. Other portions of the tube then take up the action, which thus passes on to the end of the canal by a series of alternate *wave-like* contractions.

4. According to some writers, the *longitudinal muscular* fibres aid *peristalsis* by extending themselves behind, so as to slip over the contained substance, and then contracting with it and carrying it forward.

Let A, B, C, and D be four continuous and successive portions of the intestinal canal. On the commencement of the *peristalsis*, the food, arriving at the portion of the tube represented by A, *stimulates* its walls to *contract* upon it, the substance being driven downward into the *unconstricted* or *relaxed* part of the tube *next below* it. This portion of the tube, represented by B, now *contracts* on its contents, *expelling* a portion of them. If, while B is contracting, segment A of the tube were to *relax*, portions of the *chyme* would be driven *backward* as well as *forward;* the segment A, therefore, does *not* relax *until* the segment C *next below* it has become constricted, and propelled a portion of its contents into the part D, when the segment A becomes relaxed. This series of actions is then taken up by segments of the tube *next below* in *succession*, until it has passed to the end of the canal. This action is *not*, however, continuous, but *intermittent* or *rhythmic*. According to some writers, this movement is sometimes *reversed*, the fibres contracting from *below* upwards in place of their *normal* succession from *above* downward; this constitutes *anti-peristalsis;* its existence is, however, doubted

by Dr. Brinton and other modern physiologists of eminence. The ordinary contractions of *peristalsis*, combined with the obstructive action of any obstacle sufficiently powerful to prevent the onward progress of the food, are quite sufficient to explain the production of a deflected or return current through the central or *axial* part of the tube. The *normal* peristalsis of the bowels is much less vigorous than that of the stomach. Dr. Brinton states that a continuous peristalsis of even two inches per minute would amount "to that of a violent and exhaustive diarrhœa in the human subject."

The peristaltic movements of the intestines have been actually observed during life in men and the inferior animals. In certain cases of extreme emaciation the abdominal walls have been so thin as to permit of these movements being distinctly observed in the human being. It may also be occasionally seen in ordinary persons, when a portion of the intestinal tube is obstructed, so as to cause the *peristaltic* action to become *unusually powerful* and well marked in its attempt to remove the obstacle. During surgical operations it may sometimes be observed very distinctly. Similar movements may be observed on opening the *abdomen* of animals immediately after death; these movements, which are probably much more violent than those that take place during life, are due to the *stimulus* of the cold air. They may be produced with great energy by passing strong currents of *magneto-electricity* through the intestines of an animal but recently dead. Chemical and mechanical irritation of their muscular coat also produce them.

The action of *peristalsis* may be readily seen in a rabbit which has been recently fed. To prevent

cruelty, first stun it by a blow over the top of the neck, which renders it insensible, and then open the abdomen, when the *peristaltic* action of its bowels will be distinctly seen.

Various attempts have been made, but without much success, to determine the *velocity* of the *peristaltic* movement. It has been estimated that the food takes about two and a half hours to traverse the *small* intestine.

Dr. Busch found that food appeared at an artificial opening at the top of the *jejunum* in from twenty-two to thirty minutes after its *ingestion*. Dr. Braune states that he found the *first* portions of the food to present themselves at an *artificial* opening immediately above the *ileo-cæcal* valve about three hours, and the last portions about six hours, after ingestion.

Ludwig and Schwarzenberg made artificial *fistulæ* or openings into the intestines of certain dogs. Into these openings they introduced balls of wax attached to fine leaden wires. In this manner they proved that solid bodies always excited a *peristaltic* movement in the direction of the *rectum*.

The propulsion of the food through the intestines is greatly aided by *bodily exercise*, which, by bringing the *abdominal* and *thoracic* walls into play, shakes up and agitates the intestinal contents, and compresses and, as it were, kneads the bowels; thus both stimulating their *peristaltic* action, and propelling the food or its residue by its direct *mechanical* action. The absence of this important *auxiliary* to the action of the bowels renders the *sedentary* so liable to *constipation*, or the *sluggish* action of the intestines, with all its attendant evils.

Probably there are no organs in the body which manifest so strong a tendency to *periodicity* of action

as the intestines; and it is the opinion of many leading physiologists that no function of the body can be so easily regulated as the action of the bowels: yet when this tendency has been *long thwarted* there are probably few organs of the body whose regular and healthy action it is more difficult to restore. Every person should make it a *habit*, as a matter of personal duty, to discharge the contents of the bowels once at least in every twenty-four hours. Even when by neglect, or other circumstances, this natural regularity of action has been lost, it may in most instances be re-established by perseverance in the *attempt* to empty them regularly every day at a fixed hour.

Constipation.—Action of Purgatives (from L., *con*, together, and *stipo*, I cram).—When the bowels are *sluggish* and *inactive*, they become crowded with *fæces*, and *constipation* or costiveness is produced. This state may result from the too feeble *peristaltic* action of the *muscular coats*, or the *low* state of activity of the *mucous membrane*. In the former case the *constipation* or costiveness may be temporarily removed by those medicines, as *rhubarb*, *aloes*, *colocynth*, &c., which act on the *muscular* coat, exciting it to increased activity. In the *latter* case it is more beneficially removed by the action of *salines*, as *Epsom* salts, &c., which act upon the *mucous membrane*, stimulating it to *secrete* an excess of fluid from the *serum* of the blood, by which the solid contents of the bowels are *dissolved* down and *washed* away. In either case the practice, though it may be attended with *temporary* benefit to the system, is decidedly *injurious* to the organs immediately acted upon. The purgative action of *mercurial* compounds is partially due to the increased *quantity* of *bile* which is poured into the intestine; this increase is consequent on the

exalted action of the liver, which is excited by these compounds.

Cause of Peristalsis.—The *peristaltic* contractions are produced partly by the *stimulus* of the food or solid substances acting directly on the *organic muscular fibre*, and partly by *nervous* action through the agency of the *spinal cord.* They are also probably excited by the distension of the *muscular fibres* by intestinal gas. *Peristaltic* movements may be excited by irritation of the *solar plexus* or the *semilunar ganglia*, and the *sympathetic ganglia* of the neck: irritation of the first three *cervical spinal nerves*, and the *cervical* portion of the *sympathetic nerves*, excites *peristaltic* movements in the *œsophagus.* Irritation of the roots of the lower *cervical spinal nerves* of the lowest *sympathetic ganglion* of the neck, and of the higher *sympathetic ganglia* (see "Nervous System"), produces contractions in the *lower* portions of the *œsophagus.*

Irritation of the 4th, 5th, 6th, and 7th *cervical spinal nerves*, and of the 1st *thoracic nerve*, produces contractions in the *stomach* of a rabbit; and the *lower* the nerve irritated, the *lower* or the nearer the *pylorus* are the contractions produced. Irritation of the *dorsal*, *lumbar*, *sacral*, and other *spinal* nerves produces contractions in other parts of the canal, according to the part of the *spinal cord* irritated.

Krause believes the *peristaltic* movements to be due to the circulation of *venous* blood, or blood which is deficient in oxygen. Dr. Carpenter is of opinion they, to a very great extent, depend upon the direct *stimulus* of the *organic* muscular fibre. The presence of the *bile* also promotes the *peristaltic* action of the bowels, producing, when in great excess, powerful *diarrhœa.*

The Serous Coat of the Intestines is derived from the *peritoneum*, and resembles it in its general characters. (See " Tissues," "Serous Membrane.")

The Muscular Coats of the Intestines.—The muscular tunic of the small intestines (see Fig. 15) consists of *two layers* or planes of *unstriped* or *organic* muscular fibre, viz., a thinner *external* layer of *longitudinal*, and a thicker *internal* layer of *transverse* or *circular* muscular fibre, in which the fibres are arranged at *right angles* to the axis of the tube. The muscular coat of the intestines is two to five times thinner than that of the *stomach* or *œsophagus*, and its action is therefore much less powerful. The muscular coat of the large intestines also consists of a layer of *longitudinal* and a layer of *circular organic* muscular fibre; but the greater number of the *external longitudinal* fibres are collected into three flat *bands*, about one-half of an inch wide, which extend from the base of the *cæcum* to the *rectum*. These longitudinal muscular bands are about one-third *shorter* than the *cæcum* and *colon*, to which they are attached, in consequence of which they *pucker* up this portion of the intestine, producing the *sacculi* previously described. When they are dissected off the *sacculi* disappear, the walls of the tube becoming smooth and uniform.

The Mucous Coat of the Intestines consists of the *compound* variety; its great thickness arises from its involution into *tubuli*. (See Figs. 15 and 16.) The *mucous membrane* of the *small* intestine is *villous*, that of the *large* intestines is *smooth* and *destitute of villi*. The *mucous membrane* of both large and small intestines contains *tubuli* and *solitary* glands. (See " Structure of Mucous Membrane.")

The Bloodvessels of the Intestines.—The *duodenum* is supplied with arteries derived from the

cœliac axis (Fig. 26). The arteries which supply the *lower* part of the *duodenum*, the *ileum*, the *cæcum*, and the ascending and transverse *colon*, are derived from the *superior mesenteric* artery (Fig. 26) after repeated *bifurcations* (dividing in twos) and *anastomoses*. These branches or subdivisions are named according to the parts of the intestines they supply, as the right colic, ileo-colic, &c. The descending *colon*, *sigmoid flexure*, and *rectum* derive their arteries from the *inferior mesenteric artery* (Fig. 26), which also *bifurcates*, and *anastomoses* very freely before giving off the ultimate branches which supply the parts named.

The *veins* of the intestines correspond with the *arteries;* the chief veins are the *superior* and *inferior mesenteric*. They commence in the arterial *capillaries*, and terminate in the *portal vein*, which distributes the *venous* blood from the intestines through the *liver*.

The Nerves of the Intestines are derived from the *epigastric* or *solar plexus* of the sympathetic system. The intestines are also probably brought into relation with the *spinal* nerves and *medulla oblongata* through the sympathetic system. That the functions of the intestines are performed to a great extent independently of the *cerebro-spinal* system is shown by the fact that the chief operations of the intestines are not arrested by the section or destruction of the *spinal cord*. (See "Nervous System.")

The Intestinal Juice is described as a viscid, transparent, colourless, structureless, *alkaline* fluid, generally containing a slight admixture of *cell* growth. It, like the *saliva*, acts very powerfully on *starch*, converting it into *sugar*. It contains 2 to 4 per cent. *solid* matter. Its specific gravity is about 1010. Considerable difference of opinion prevails among physiologists as to its action on the *protein* compounds.

Bidder and Schmidt state, as the result of their experiments on dogs, that its *solvent* power over *albuminous* compounds is greater than that of the *gastric juice* itself. Lehman and Frerichs, on the other hand, state that pure intestinal juice has no *solvent* power whatever over the *protein* compounds. Great difficulty is experienced in obtaining *pure intestinal juice*, because of its almost constant admixture with *bile* and *pancreatic* juice. Frerichs attempted to obtain it *pure* by tying *ligatures* round a portion of the *small intestines* of a dog, replacing the intestine in the abdomen, and examining its fluid contents after a few hours. Busch obtained it from the intestines of a woman who had a *fistula* or opening by which the contents of the *stomach* and *duodenum*, including the *gastric* and *pancreatic* juices, and the *bile*, escaped, instead of passing into the intestine. In all such cases, however, it is highly probable that the *secretion* becomes more or less altered by the *shock*, inflammation, &c., produced by the surgical injury, and the more or less *diseased* condition of the intestines where fistulous openings exist. In some of the experiments referred to, an opening was made in the *abdomen* of a dog, a portion of the *small intestine* was drawn out, and tied, to prevent the *bile* and *gastric juice* from passing into it; an incision was then made, through which *weighed* portions of meat, contained in small linen bags, were introduced, and allowed to remain in the bowel some hours; after which they were removed, weighed, and examined, when it was found that they had lost weight, a portion of the food having been *digested* and *absorbed*, and that the remainder was also partially *digested*. There can, therefore, be but little doubt that pure *intestinal juice* exerts great *solvent* power over *protein* compounds. This power is, however, greatly increased by admixture

with the *gastric* and *pancreatic* juices and the *bile*. Probably an important function of the *intestinal juice* is the *neutralization* of the *acidity* of the *chyme*.

The Bile is a greenish yellow *alkaline* fluid, secreted from the *portal* blood by the *liver*. It acts chiefly on the *fatty* portions of the food. This secretion is more fully described under "Organs of Secretion." (See "Liver and Bile.")

The Pancreatic Juice is a clear, colourless, alkaline fluid, secreted by the *pancreas*. It acts upon the *starchy* constituents of the food, converting them into sugar; also upon the fats. Its action on the *protein* compounds is not yet satisfactorily determined. It very much resembles the *saliva*, and probably promotes the action of *endosmose* in the intestines by its fluidity. This substance is also more fully described under "Organs of Secretion." (See "Pancreas," &c.)

The Chyle (from Gr., *chulos*, juice) is the nutritious fluid which is formed in the intestines immediately after the admixture of the *bile* and *pancreatic* juice with the *chyme*, and is absorbed by the *lacteals*. It varies very much in appearance, according to the *time* after the last meal, and to the *part* of the *lacteals* at which it is collected. In some old works, and also according to the popular notion, it forms the very *essence* of the *nutriment*. This view, however, is erroneous, as by far the *larger* part of the nutriment is absorbed into the blood through the *veins* of the *stomach and intestines*. It has been estimated by Bidder and Schmidt that 6 lbs. of this fluid are poured into the circulation daily. When collected from the *receptaculum chyli* a few hours after an ordinary meal, it forms a *milky*, yellowish white, opaque, or opalescent, feebly *alkaline* fluid, having a slightly *saline*, mawkish taste. It is feebly *coagulable*, and very closely re-

sembles *lymph*, except in the large quantity of *fatty* matter it contains, which forms its most distinctive constituent. When collected *fasting* it is transparent, and can scarcely be distinguished from ordinary *lymph*. *Chyle* which has been exposed to the *air* acquires a *reddish* colour. When it is collected from the upper part of the *thoracic duct* it has a *pinkish* hue, contains a larger number of *chyle corpuscles*, and a greater quantity of *fibrin*. When examined under a microscope it is found to consist of a clear transparent fluid, containing *chyle corpuscles*, about 1-4,600th inch in diameter; oil globules, 1-2,500th to 1-2,000th inch in diameter; and minute *molecules* of *fatty matter* which do not coalesce, probably because of an *albuminous* coating, but are *soluble* in ether. Mr. Gulliver attributes the *milky opacity* of the *chyle* to these particles, which he terms the *molecular base* of chyle. He describes them as *spherical*, and having an average diameter of about 1-30,000th of an inch. The *milky* colour of the *serum* of healthy blood, which is sometimes observed after a full meal, is due to the presence of this *molecular base*. When an animal is fed on flesh diet containing no *fatty* matter the *chyle* becomes *colourless* and quite transparent.

Dr. C. Owen Rees gives the following analysis of chyle, taken from the *thoracic duct* of a criminal, who had taken, the night previously to his execution, a meal consisting of bread, meat, and tea, and some toast an hour before execution :—

COMPOSITION OF CHYLE.

Water			90·48
Solid residue	Albumen and Fibrin .	7·08	= 9·52
	Water extractive . .	0·56	
	Osmazome . . .	0·52	
	Salts (similar to those of serum)	0·44	
	Fat	0·92	
			100

In this instance the *chyle* probably contained less than its normal quantity of *fatty* matter, the man being practically, as far as the *chyle* was concerned, in a state of fasting, the toast not yet having had time to yield chyle.

The Chyle Corpuscles are minute, globular, spheroidal, *nucleated* cells, comprising, when well developed, a *cell wall* and *contents*. (See D, Fig. 22.) Occasionally they present very *amœba-like* changes of form; their diameter varies from 1-7,000th to 1-2,600th of an inch in diameter. (See "Structure of Cells.")

These *corpuscles* probably develop into the *white* or colourless *blood* corpuscles, the *nuclei* of which again probably develop into the true *red corpuscle* of the blood. The number of these *corpuscles*, and also the quantity of *fibrin*, greatly increase after the *chyle* has passed through the *mesenteric* glands, and during its passage through the *thoracic duct*, when it becomes more *highly organized*, assimilating more in its character to that of true blood. (See "White and Colourless Blood Corpuscles.")

The Fæces (from L., *fæx*, dregs), or excrementitious matter expelled from the large intestine, consist of the *undigested residue* of the food, a portion of the *bile*, probably including the whole of its colouring matter, *mucus*, *epithelium scales*, and probably a small portion of the *disintegrated tissues*. The *quantity* varies from 1-10th to 1-4th of the weight of the solid food. About 2 to 10 oz. are passed daily, containing about 25 per cent. of solid matter, and 75 per cent. of water.

The undigested fæcal residue of *animal* food, as distinguished by the microscope, consists of the *sarcolemma* of muscular fibre, the *white* and *yellow fibres* of areolar tissue, the *walls* of fat cells, *cartilage cells*, *fat*, and also

frequently, *muscular fibre* itself. The fæcal residue from *vegetable* food consists of *cellulose*, forming the vessels, cells, and fibres of plants, *starch cells*, and *starch grains.*

The fæces in general have an *acid* reaction, but are sometimes *neutral* or *alkaline.* About 23 to 31 per cent. of dry fæces consist of *inorganic ash*, the proportion of mineral matter being greatest when a purely *flesh* diet is adopted. The following table shows the composition of this ash :—

Chlorides and sulphates of potash and soda	1·367	soluble in water.
Bibasic phosphate of soda	2·633	
Phosphates of lime and magnesia . . .	80·372	insoluble in water.
Phosphate of iron	2·090	
Sulphate of lime	4·530	
Silica	7·940	

The *peculiar* and *offensive odour* of the fæces is not derived from the *undigested food.* Drs. Liebig and Carpenter attribute it to the presence of *partially oxidated tissues* excreted into the large intestine.

Dr. Ed. Smith found the average weight of the fæces excreted daily by prisoners at the Coldbath Fields prison, who were fed on full diet, was 8·55 oz., containing about 73·5 per cent. of water, and 41·8 grs. of *nitrogen.* The longer the fæces remain in the intestines the harder and more solid they become, in consequence of the absorption of the liquid portion. The peculiar hard rounded masses (termed *scybalæ*) of the fæces of the sheep and other similar animals acquire their peculiar form from the *sacculi* of the large intestine, in which they are lodged previous to their passage into the *rectum.* The human fæces sometimes acquire this character when they have been retained very long in the intestines.

Gases of the Alimentary Canal.—The gases

in the stomach and intestines may be produced —1, by the *absorption* of the *oxygen* of the air; 2, by the decomposition of the *food;* 3, by the decomposition of the *fluids excreted* into the alimentary canal. It was formerly supposed that they were also *secreted* by the walls of the stomach and intestines, but this opinion is now generally abandoned. In some cases of *dyspepsia* (indigestion), also in some nervous diseases, as *hysteria*, these gases are developed in excessive quantities. This morbid condition constitutes *flatulence.* In the disease termed *tympanites* the abdomen is distended like a drum, the pressure of the gases in some cases impeding the process of breathing, so as to produce *death* by suffocation. The gases chiefly found in the alimentary canal are nitrogen, carbonic acid, hydrogen, carburetted hydrogen, and traces of sulphuretted hydrogen. The *stomach* also contains *oxygen* mixed with a large proportion of nitrogen and carbonic acid.

What becomes of a Piece of Bread when eaten? 1. The bread is *masticated* (broken into little masses and well pounded), by which the *cohesion* of its particles is partially overcome, and their *solution* greatly facilitated. 2. It is mixed with *saliva*, which *lubricates* it, and facilitates the process of swallowing. 3. It is swallowed (forced down the œsophagus by the action of its muscles). 4. It is mixed with *gastric juice* in the stomach—the *gastric juice* dissolves the *gluten*, the *nitrogenous* constituent of the bread, forming a solution of *peptone*, which is *partially* absorbed by the *veins* of the stomach—portions of the *starch* are acted upon by the *saliva* and changed into *sugar*, some of which is also absorbed by the gastric *veins;* the unabsorbed portions form *chyme.* 5. The *chyme* is forced by the vermicular contractions of the stomach

into the intestines, where it meets with the *bile*, and the *pancreatic* and *intestinal* juices; the remaining portions of the dissolved *peptone* are absorbed, and the conversion of starch into sugar by the *saliva*, now aided by the *pancreatic* and *intestinal* juices, is completed, and the dissolved sugar *absorbed*. 6. The undigested residue, consisting chiefly of *cellulose*, starch *cells*, *starch*, &c., is passed out of the canal.

Butter.—If butter be eaten with bread, the butter is converted into an *emulsion* by the action of the *bile* and *pancreatic juice*, and absorbed in the form of *chyle* by the *lacteals*.

What becomes of a Mutton Chop when eaten?—A mutton chop when eaten undergoes the first *three* processes, the same as a piece of bread. 4. On arriving in the stomach it is mixed with the *gastric juice*, which dissolves a portion of the *protein* compounds, forming them into *peptone*, which is partially absorbed, and into *chyme*. 5. The *chyme* is forced into the duodenum and mixed with the *bile*, and the *pancreatic* and *intestinal juices;* the remainder of the soluble *protein* compounds are changed into *peptone* and absorbed as they are forced through the canal, the *pancreatic* and *intestinal juices* aiding this process. The *fat* is converted into an *emulsion* and *absorbed* by the lacteals. 6. The remainder, consisting of the indigestible portions, including the *sarcolemma*, the *cartilage cells*, the *fibrous* portions of the *areolar tissue*, and of the *veins* and *arteries*, are expelled from the intestines. When the quantity of food taken is greater than the wants of the system require, or the digestive power is impaired, a considerable portion of *partially* digested food also escapes with the *true* digestive residuum.

Eggs, raw or boiled, undergo a similar series of

changes, the peptone formed from the liquid albumen being chiefly absorbed after its passage into the intestine, and leaving little or no residuum.

ABSORPTION.

THE LYMPHATICS AND LACTEALS.

Absorption.—In addition to the *general* absorptive power possessed by the *veins*, to which continual reference has been made in describing the digestive processes, a peculiar absorptive power is exercised by a special system of vessels, termed *absorbents* or *lymphatics*, so named because of the *lymph* they contain. A case of diabetes, illustrating this power, is mentioned, in which the patient must have absorbed 113 pounds of water from the atmosphere in the course of five weeks; other similar cases are on record. An equally interesting case is also described of a jockey, who having reduced himself to the proper weight that he might ride that morning, took one cup of tea only, very shortly after which his weight was found to have increased six pounds, whereby he was prevented from riding. In this case the tea must have *stimulated* the *absorbents* into action, causing them to imbibe aqueous vapour from the atmosphere. But whether this absorption was effected by the smaller veins or the lymphatics, or through the lungs or the skin, is uncertain; most probably all these agents participated in the process.

The *absorbent* system consists of the thoracic duct, right lymphatic duct, receptaculum chyli, lymphatic and lacteal vessels, and the lymphatic and mesenteric glands. (Fig. 20.)

Distribution and Course of the Lymphatics.—The *lymphatics* commence in minute tubes a little

larger than the capillaries, which ramify and anastomose freely, producing by their repeated junctions larger vessels, which follow the general course of the veins, and ultimately discharge their contents into the right and left subclavian veins. The latter vessels pour it into the descending *vena cava;* from thence it passes into the *right* side of the heart, which propels it into the *lungs*, where the useful portions become *sanguified*, or converted into blood. The distinction made by physiologists between the *lacteals* and *lymphatics* is essentially an *artificial* one.

The lymphatics are distributed all through the body except the brain, spinal cord, and the interior of the eye. They form two sets, the *deep* and the *superficial* lymphatics. The *lymphatic glands* are very numerous in some parts of the body. The principal glands are —the *cervical* (in the neck), the *axillary* (in the arm-pit), the *lumbar* (in the loins), the *inguinal* (in the groin), the *mesenteric* (see Fig. 20), (in the folds of the mesentery), and the *femoral lymphatics* (on the inner side of the thigh).

Structure of the Lymphatics.—The *larger* lymphatics possess a similar structure to that of the veins, consisting of three coats, viz.—1, an *external* fibrous coat, consisting of compact *areolar* tissue; 2, a *middle* elastic coat of yellow elastic fibre, and of circular unstriped muscular fibres; 3, an *inner* coat of spindle-shaped epithelial cells supported on a thin network of elastic fibre. They are very abundantly supplied with semilunar *valves* (similar to those shown in Fig. 28) of fibrous tissue covered with epithelium, which are placed at very short intervals, their *concavities* being turned towards the heart, or in the direction in which the current flows. These *valves* are much more *numerous* than in the veins. The *walls* of the lym-

phatics expand immediately above each *valve* into a sort of pouch; these *expansions* give them a very irregular *beaded* or *jointed* appearance. Their appearance is best seen when the vessels are distended with lymph. The smaller vessels are composed of a *transparent homogeneous* membrane, and are destitute of valves; being filled with a *transparent* fluid (the lymph), they are in general almost *invisible*. Some animals, as the frog, are provided with little pulsating *sacs* or pouches (expansions of the lymphatic vessels), termed *lymphatic hearts*, the movements of which help to *propel* the contained lymph.

Structure of the Lymphatic Glands.—The lymphatic glands are small, firm, flattened, oval bodies, varying from the size of a hemp-seed to that of an almond, which are situated in the *course* of the *lymphatic* and *lacteal* vessels. They are of a pinkish colour, unless stained by absorbed matter, as in the *lungs*, where they are rendered black by the carbon; in the *liver*, where they are stained yellow by the bile; or in the *mesentery*, where they are white from the chyle. They are invested by a *capsule* of areolar tissue, prolongations of which dip into the interior of the gland, forming a series of *septa* or partitions, which form an internal framework, more or less completely filled with a *medullary* substance, consisting of *dotted corpuscles*. It is supposed these *corpuscles* play an important part in elaborating or *organizing* the *lymph* or *chyle* which traverses the gland.

The *afferent* (from L., *ad*, to, and *fero*, I carry) lymphatic vessels, in their course *towards* the *thoracic* and *lymphatic ducts*, divide into several smaller branches immediately before *entering* the gland. As they enter the gland they lose their external coat, which is continuous with that of the gland; after entering the gland

they become very *tortuous*, *subdividing* and forming a *plexus*. The vessels of this *plexus* unite to form the *efferent* (from L., *ex*, out, and *fero*, I carry) vessels, which, on *emerging* from the gland, again receive their external coat. The *efferent* vessels are in general *larger*, but *less numerous*, than the *afferent* vessels. The lymphatic glands are abundantly supplied with capillaries.

The Function of the Lymphatics and their Glands is to *collect*, *elaborate*, and *convey* the lymph from the various parts of the body to the subclavian veins, where it is poured into the blood. The lymphatics have been compared to a system of *sewerage*, draining off the waste fluids from the tissues into the blood, what remains that is *useful* in the lymph being *assimilated*, and what is purely *excrementitious* being *removed* in the various processes of *excretion*.

The lymphatics possess a marked power of absorbing certain injurious, morbid, and poisonous substances, such as the virus of small-pox, vaccine lymph, the poison absorbed through a wound in dissection. In the latter and similar cases the lymphatic vessels of the arm, and the glands in the armpit, become swollen and inflamed, the glands suppurating and becoming ulcerated, apparently in their attempt to arrest the injurious substances and cast them out of the body. Other substances, however, which are refused by the lymphatics are readily absorbed by the smaller veins of the skin and alimentary canal.

The Lymph (from L., *lympha*, water) is a clear, transparent, colourless, or yellowish fluid, containing a number of minute colourless, spherical, nucleated corpuscles, termed *lymph corpuscles* (see D, Fig. 22), which resemble the *white corpuscles* of the blood. It is slightly *alkaline*, and *coagulates* spontaneously, in consequence of the presence of *fibrin*. It also, in

general, contains, especially after a meal, a greater or less number of minute oil globules. The *lymph* very closely resembles the *chyle* of a fasting animal; it is also very similar to the *liquor sanguinis*, or liquid part of the blood, differing from it chiefly in the *larger* quantity of *water* it contains. The following table shows the result of the analysis of *lymph* obtained from the thigh of a healthy middle-aged woman :—

COMPOSITION OF LYMPH.

Water			93·99
Solids	Fibrin .	·056	6·01
	Albumen .	4·275	
	Fat . .	·382	
	Extractives	·570	
	Salts .	·730	
			100·00

The exact *source* and *uses* of the lymph are not certainly known. Dr. Carpenter and most modern physiologists regard it as consisting of the unappropriated and the partially exhausted *liquor sanguinis*, which has exuded through the walls of the capillaries to bathe and *nourish* the tissues, and also of portions of the disintegrated tissues which still contain material capable of affording nutriment to a different class of structures. According to this view much of the lymph consists simply of the *liquor sanguinis*, which has passed out of the capillaries, and is again returned to the circulation by another source. The *lymph* is found to be more highly organized, and to contain a greater number of *corpuscles*, after it has passed through the lymphatic glands. Bidder and Schmidt estimated that about 22 lbs. of lymph and 6½ lbs. of chyle were daily poured into the subclavian veins, the latter being formed from the food ingested.

The Lacteals (from L., *lac*, milk), or *chyliferous vessels*, are the *lymphatics* of the intestines; they derive their peculiar appearance and their name from the milk-like fluid, *chyle*, they usually contain a few hours after a meal. They originate in the *mucous* membrane, and especially the *villi* of the intestines, forming a close network in the submucous areolar tissue. The *primitive* lacteals in the centres of the villi are 1-1,000th to 1-800th of an inch in diameter. The *function* of the lacteals is to absorb, elaborate, and convey the *chyle* from the intestine to the *thoracic duct*. Their general structure is similar to that of the rest of the lymphatic vessels; they are seen when full of chyle like white threads in the mesentery.

The Mesenteric Glands are the *lymphatic glands* of the *lacteals*; they are contained within the layers of the *mesentery*. (See Fig. 20.) Their number varies from about 100 to 150, and their size from that of a pea to that of a small almond. The number of the *corpuscles* increases considerably after the *chyle* has passed through these glands. In scrofulous children these glands swell and become hardened, making the abdomen hard and prominent, and seriously interfering with the nutrition of the child.

The Thoracic Duct is the main trunk of the lacteals and lymphatic vessels. (See Fig. 20.) It commences in the abdomen, about opposite the second lumbar vertebra, and terminates at the left side of the root of the neck; it is about 18 to 20 inches long, and about the diameter of an ordinary goose-quill. It leaves the abdomen by the *aortic* opening in the *diaphragm*, ascends to the neck, then *curves* downwards, terminating in the *left subclavian* vein at the angle formed by its junction with the *jugular* vein. Its terminal orifice is furnished with a

pair of *valves* to prevent the *regurgitation* of the venous blood into the duct. The *thoracic duct* commences in an elongated pouch or expansion termed the *receptaculum chyli*, which receives four to six large trunks

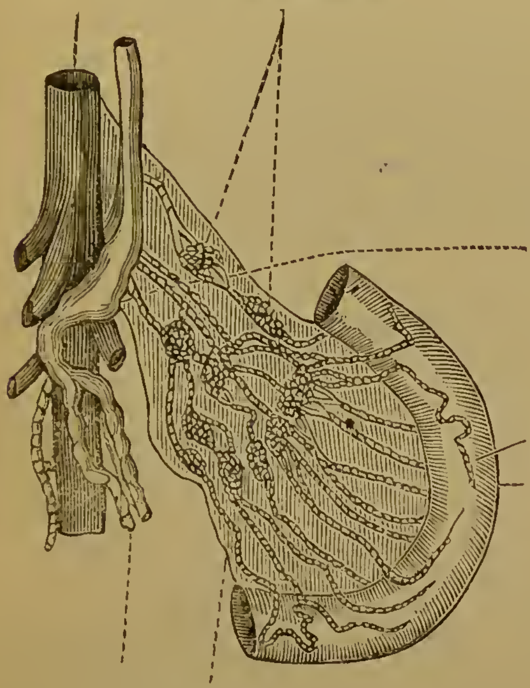


Fig. 20.—THORACIC DUCT AND LACTEALS.
Showing thoracic duct receiving *lymphatic* and *lacteal* vessels.

(see Fig. 20), formed by the combination of the lymphatics of the lower extremities. It differs but slightly in structure from the larger lymphatic vessels previously described, but is more abundantly supplied with muscular fibre, portions of which in the external coat are collected into isolated *fasciculi* or bundles. The

right lymphatic duct conveys lymph from the right side of the head, neck, trunk, and the right arm, to the right subclavian vein.

Movements of the Lymph and Chyle.—The current of the lymph and chyle flows in the direction of the heart. Its velocity, which varies at different periods and in different parts of the body, has not yet been determined with any degree of accuracy. Weiss stated that the *lymph* moves at the rate of 1-6th of an inch per second in the vessels of the neck, but it moves with much greater rapidity in the smaller vessels. Cruikshank stated that the chyle flows through the lacteals at the rate of about four inches per second.

The Forces which propel the Chyle are—1, the *endosmic* and *selective* power which causes the passage of the chyle into the lacteals; 2, the *contractions* of the *muscular tunics* which surround the central lacteals of the *villi;* 3, the *compression* of the *lacteals* by the *peristaltie* contractions of the intestine; 4, the *contraction* of the walls of the larger vessels, which by reducing their internal capacity expels a portion of their contents, the *valvular* arrangement only permitting the *chyle* to move forwards; 5, the *movements* of respiration: during *expiration* the pressure of the abdominal walls compresses the lacteals and drives the chyle onwards; during *inspiration* the tendency to a *vacuum* consequent on the enlargement of the cavity of the chest causes the *lymph* and *chyle*, as well as the air, to rush into the *thorax*, so that the chyle in the abdominal part of the *thoracic* duct is driven into the thoracic portion. These forces constitute a considerable *vis à tergo* (force from behind), driving the *chyle* forward. To this may be added, 6, the *vis à fronte* (force from before) exerted by the suction power con-

sequent on the rapid passage of the blood through the *subclavian vein*, just as a *rapid* current in a *large* sewer *accelerates* the flow of a *smaller* one opening transversely into it.

The *movement* of the *lymph* in the lymphatic vessels is effected through similar agencies (except that given under number 2) to those which determine the progress of the *chyle*. To these may be added, 7, the effects of muscular exercise, during which the contraction of the muscles compresses the walls of the vessels, imparting *motion* to their contents, which, in consequence of their *valvular* arrangement, must necessarily be *onward*. If the *thoracic duct* be tied it quickly becomes distended below the ligature, and will ultimately burst from the pressure of its contents if the ligature be not removed. The action of the *valves*, and the effects of *exercise* on the system, will be better understood after reading the paragraphs on *respiration* and *circulation* given hereafter. (See "Summary of Digestion" on next page.)

FOOD—HUNGER AND THIRST.

It has already been shown, in the chapter on *waste*, that the animal body is in a state of constant renovation and decay; that every point in its substance is the seat of a perpetual series of births of new particles and deaths of old ones, thus necessitating the continual introduction of new material to occupy the place of the old, worn-out, and effete tissues. The new material ingested into the body to supply the place of the old is termed *food*.

Two different series of changes of decay are in continual progress, viz. :—1. A process of *combustion*, by which the *animal heat* is developed and sustained. 2. A process by which the *tissues* of the various organs

Summary of Digestion and Organs of Digestion.

Processes.

Preliminary processes.
- Prehension.
- Incision.
- Mastication.
- Insalivation.
- Deglutition.

Gastric digestion.
- Secretion of gastric juice.
- Solution of protein compounds and formation of peptone.
- Conversion of starch into sugar.
- Absorption of peptone and sugar.
- Chymification.

Intestinal digestion.
- Chylification.
- Absorption of chyle and fats.
- Absorption of remaining peptone.
- Completion of the metamorphosis of starch into sugar.
- Absorption of remaining sugar.
- Defecation.

Digestive juices.

Solvents		*lbs.*
Saliva	daily	3 to 4
Gastric juice	,,	13 to 26
Intestinal	,,	½
Bile	,,	3 to 5
Pancreatic juice	,,	½
Mucus	,,	
		20 to 36

Organs.

Preparatory organs.
- Lips.
- Teeth.
- Tongue.
- Cheeks.
- Salivary glands.

Alimentary canal.
- Mouth.
- Fauces.
- Pharynx.
- Œsophagus.
- Stomach.
- Duodenum.
- Jejunum.
- Ileum.
- Cæcum.
- Appendix vermiformis.
- Colon
  - Ascending.
  - Transverse.
  - Descending.
  - ,, Sigmoid flexure.
- Rectum.

Digestive glands.
- Salivary glands.
- Liver.
- Pancreas.
- Brunner's glands.

Coats of alimentary canal.
- Serous coat.
- Muscular coat.
- Areolar or submucous coat.
- Mucous coat.

Auxiliary structures.
- Valvulæ conniventes.
- Villi.
- Gastric tubuli.
- Intestinal tubuli.
- Peyer's patches.
- Solitary glands.

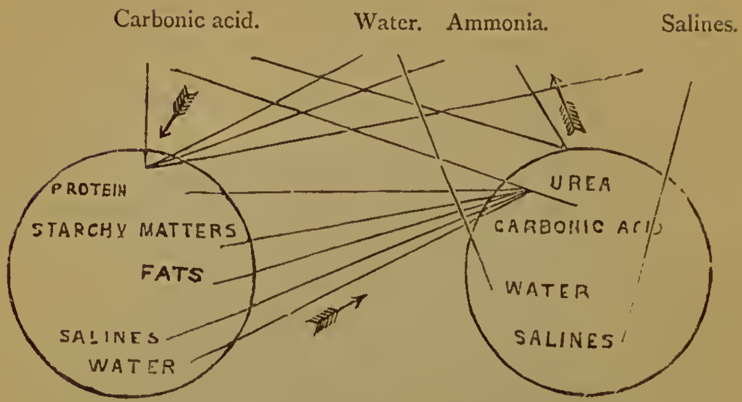
are *disintegrated* in the *performance* of their respective *functions*. Two kinds of food are therefore rendered necessary, viz. :—1. *Heat-forming*, *respiratory*, or *fuel* food, to supply the animal heat. 2. *Flesh* or *tissue-forming* food, to supply the elements of growth, repair, and renovation.

Functions of Plants in Relation to Animal Life.—The *animal* body has very little chemical *constructive* or *synthetic* power; it cannot therefore subsist on mineral or inorganic matter. It has no power to *construct* the *proximate principles* of which its *tissues* are *built up;* it must therefore be supplied with these principles *ready made*, or it cannot *exist*. This is the grand function of plants. Plants possess the *constructive* power in which the animal is deficient; they *build up* and supply its *proximate principles;* they alone render animal existence possible, and thus form the intermediate link connecting *animal life* with *inanimate nature*.

An animal cannot live on air, water, sand, or other mineral substance; a plant not only subsists on these substances, but *elaborates* from them into its own tissues the very elements necessary to the development, growth, and sustenance of the animal.

The vegetable world is therefore, as it were, an immense natural manufactory of the *raw material* of the animal structure. The plant itself is worked up from still simpler materials, viz., carbonic acid, water, ammonia, and certain salts. The following diagram from Prof. Huxley's "Lectures on Organic Nature" shows this relation very clearly :—

INORGANIC WORLD.



VEGETABLE WORLD. Fig. 21. ANIMAL WORLD.

The plant gathers and *absorbs* carbonic acid, water, and ammonia from the atmosphere, and minute quantities of earthy salts from the soil. It decomposes the *carbonic acid*, evolving its *oxygen*, which again restores purity to the atmosphere. A portion of the absorbed *carbon*, *hydrogen*, and *oxygen* it converts into *woody fibre*, *sugar*, *starch*, &c., while out of other portions of these elements, together with *nitrogen*, it elaborates the higher and more complex *protein* compounds indispensable for the development and sustenance of animal life. The animal eats the plant, assimilates its *protein* compounds, which it elaborates into its own tissues; appropriates the *starch* and the *sugar* as *fuel* to sustain the combustion necessary for the development of its internal heat; inhales *oxygen*, which at the same time develops life, but destroys the organism, *oxidizing* and burning the *starch* and *sugar*, by which they are again resolved into *carbonic acid* and *water;* and *oxidizes* and *degrades* the assimilated *protein* into *urea*, which is expelled from the organism, and resolved into *car-*

bonic acid and *ammonia*, which are destined ultimately to *re-enter* the same cycle of change. The following table by Dr. Carpenter indicates synoptically the part played by animals in the conversion of food :—

Food, consisting of albuminous and other compounds,	converted into	Living organized tissue,	and this metamorphosed into	Carbonic acid and water thrown off by respiration. Urea and biliary matter, &c., thrown off by other excretions.

These changes are incessant during the life of the animal ; but ultimately it dies, and is entirely resolved into its inorganic elements. And there can be no doubt that the material elements which formerly entered into the composition of and helped to build up the bodies of the ancient races who have long since been gathered to their fathers, now perform similar offices in the bodies of living men.

The following table shows the leading distinctions between plants and animals in relation to *food* and *digestion* :—

Animals	Vegetables
Live on highly azotized *organic* food.	Appropriate but small quantity of azotized *inorganic* food.
Live actively.	Live slowly.
Waste rapidly.	Waste slowly.
Renovate and repair slowly.	Change slowly.
Consume proximate principles.	Live on *inorganic* food.
Convert one proximate principle into another.	Build up proximate principles.
No animal is nourished by carbonic acid or ammonia.	Plants *nourished* by carbonic acid and ammonia.
Changes produced by inherent powers of organism.	Changes produced by external forces, heat, light, electricity, &c.

Quantity and Kind of Food dependent on Waste.—Food is rendered necessary by *bodily waste;* the *quantity* of food required must therefore depend on the *rate* of the waste, and the *quality* or kind of food upon the *nature* of the waste. The principal waste of the body consists of *carbonic acid* and *water* evolved from the lungs, and *urea* and *uric acid* excreted by the kidneys and the organs connected with the alimentary canal. The daily supply of food must therefore contain as much *carbon*, *hydrogen*, *nitrogen*, &c., as is daily excreted from the body in the former substances, or the body must fall into ruin. But the animal organism possesses only a very feeble constructive power; the *nitrogen* required must be therefore presented to it very nearly in that form in which it is assimilated by the body; in other words, the *nitrogen* must be presented in the form of "*protein*," or some modification of it, as *albumen*, *fibrin*, *casein*, &c., more or less similar to that which exists in the tissues. The composition of the body remaining the same, the quantity of the *nitrogenous* or *proteinous* food daily required to build up the *wasted tissues* must be such as shall contain an amount of *nitrogen* equal to that contained in the *urea* and other *nitrogenous* excretions.

By determining the daily amount of these excretions or degraded tissues, the quantity of *flesh-forming* or *nitrogenous* food which must be ingested per day, to sustain the animal body at its full weight and vigour, may be calculated with a fair degree of accuracy.

In like manner, the quantity of *carbon* that must be taken into the body *daily* in the *carbonaceous* or *heat-forming* food, must equal the quantity of *carbon* evolved from the *lungs* and the *skin* in the form of

carbonic acid, *plus* the *carbon* passed out of the system through the *bowels* and the *kidneys.*

If the whole of the food taken were digested, it would be easy to determine the amount of the excretions proper, and thus the quantity of the tissues *disintegrated* daily; but in general considerable quantities of *undigested* food pass out of the intestines with the excretions, and there is no certain mode of accurately determining the respective quantities of these *egesta.* For various reasons, to be afterwards explained, the *waste* of the *tissues* is calculated from the amount of the *urea* and *nitrogenous excreta.*

Nitrogenous Waste determined on Fasting Animals.—In order to determine the *real* or *true* nitrogenous *waste* of the *tissues* themselves, it is necessary to prevent its becoming mixed with the *nitrogenous* compounds contained in the intestines, which are derived immediately from the *food*, and not from the *tissues.* Experiments to determine the actual *azotized* waste of the tissues are therefore made on animals which have been kept one or two days *without food*, or have been fed on a diet *containing no nitrogen;* in either case the results are identical. In such instances it is quite clear, the whole of the *nitrogen* in the food having previously been passed out of the system, that the *nitrogen* contained in the excretions must have been derived *solely* from the *blood* or the *tissues.* But there is sufficient physiological evidence that these nitrogenous excreta are not derived from the *blood;* they must therefore be derived *solely* from the *tissues.* Hence the quantity of nitrogen they contain is an exact *register*, alike of the nitrogen which *was* contained in the destroyed tissues, and the nitrogen which *is* required in the food necessary for their *repair* or *renovation.*

Protein Compounds and their Disintegration.— The following chemical formula has been assigned to *protein*:—

$$(C_{36}H_{25}N_4O_{10} + 2HO) = 2\text{Urea}(C_2H_4N_2O_2) + 8HO + C_{32} + H_{11}.$$

By this formula it will be seen that 1 *atom* of *protein* would furnish by disintegration 2 *atoms* of *urea*, 8 *atoms* of water, 32 *atoms* of carbon, and 11 *atoms* of hydrogen.

All the *azotized* tissues of the body are built up and nourished by what are termed *protein* compounds, which include albumen, fibrin, casein, &c. All these bodies possess a very similar chemical composition to that assigned to *protein*. The animal organism deficient in the *constructive* power necessary to elaborate the *protein* compounds from their original elements is supposed to possess the limited constructive power necessary to *metamorphose* one *protein* compound into another, to change *albumen* into *fibrin*, &c. These compounds are modified and assimilated by the solid structure of the organs; the organs act (perform their respective functions), but they cannot act without the stimulus of the *oxygen* conveyed to them by the *arterial* blood. According to the chemical theory of this *stimulus*, during each moment of action the *oxygen* combines with certain portions of their substance, *oxidizing* and *disintegrating* or destroying them for ever, as muscle, nerve, &c., and converting them into *urea*, *uric* acid, *carbonic* acid, *water*, &c. Thus each atom of the *disintegrated protein* of the active muscle or other tissue would, when combined with 75 atoms of oxygen, yield 2 atoms of *urea*, 19 atoms of *water*, and 23 *atoms* of *carbonic acid*, as shown by the following formulæ:—

1 atom of *protein* equals $(C_{36}H_{25}N_4O_{10} + 2HO) = 2Urea(C_2H_4N_2O_2) + 8HO + C_{32} + H_{11}$.

But $\left\{ 2Urea(C_2H_4N_2O_2) + 8HO + C_{32} + H_{11} \right\} + 75O = 2Urea(C_2H_4N_2O_2) + 19HO + 32CO_2$.

In confirmation of this view, it is found in the case of animals which are fed on flesh from which all the removeable fat has been dissected off, that about seven times as much *carbon* passes off by the *lungs* in the form of *carbonic acid* gas as passes off by the *kidneys* in the form of *urea*.

As previously stated (page 23), the existence of *protein* as a distinct *principle* is not now generally admitted; nevertheless it would be difficult to explain the phenomena connected with food and nutrition without some equivalent term; the term *protein* is therefore almost universally retained by writers on food, &c.

Although the precise reaction indicated in the formula just given may not apply with mathematical accuracy, yet there is no doubt that a perfectly analogous action is effected during these changes. It is of comparatively little importance which of the *albuminous* or *protein* compounds be selected for illustration, the chemical composition of each of these bodies being nearly identical, as shown by the following table, which gives the composition per cent. of protein, albumen, fibrin, casein, and globulin, according to the analysis of Mulder:—

Ultimate Elements.	Protein from Albumen.	Albumen from hens' eggs.	Fibrin.	Casein.	Globulin.
Carbon . .	53·7	53·5	52·7	53·83	54·5
Hydrogen .	7·0	7·0	6·9	7·15	6·9
Nitrogen . .	14·2	15·5	15·4	15·65	16·5
Oxygen . .	23·5	22·0	23·5	22·52	22·1
Sulphur . .	1·6	1·6	1·2	0·85	
Phosphorus .	..	0·4	0·3	..	..
	100·0	100·0	100·0	100·0	100·0

The *rational* formula of these bodies is not yet settled. Mulder prepared *protein* by dissolving *albumen*, *fibrin*, or *casein* in a solution of *potash*, and digesting at a temperature of 140° F. until it ceases to blacken when tested with a salt of lead; acetic acid is then added, when a copious snow-white flocculent precipitate will be thrown down. When this precipitate is well washed it forms the *protein* of Mulder. It is not now regarded as a constituent of albumen, fibrin, casein, &c., but as a first product of their decomposition.

Nitrogenous Food an Exponent of Work.—It is a familiar fact that for a man or a horse to work hard he must eat well; but science alone can indicate the mathematical accuracy of the relation between *eating* and *working*. Dr. Playfair, in a most interesting, instructive, and philosophical paper recently published, entitled, "The Food of Man in Relation to his Useful Work," has produced much additional evidence, showing that the *nitrogenous* food alone becomes a source of *dynamical* or mechanical and of *mental* work. He shows that a horse may be kept

in a condition of health during a state of *quietude* when fed on 12 lbs. of hay and 5 lbs. of oats,—food containing about 29·2 oz. of nitrogenous or flesh-forming food; but that if required to do *much work*, he should get 14 lbs. of hay, 12 lbs of oats, and 2 lbs. of beans, which contain about 56·2 oz. of flesh-formers. The difference in these amounts therefore indicates the amount of the *flesh-formers* required for the performance of the *mechanical labour*, over that required for *mere subsistence*, as follows:—

Horse at *work* . .	56·2 oz.	of plastic food.
Horse at *rest* . .	29·2	„
Difference .	27·0 oz.	„

The *food equivalent* of the mechanical labour of the horse is therefore 27 oz. of flesh-formers.

Again, the amount of *flesh-forming* food required to keep an ordinary man of good health in a state of *quietude* is about 2 oz.; and the amount of *flesh-formers* required to keep the same man in a state of health when performing similar *mechanical* labour (pulling weights horizontally) is 5·5 oz.

Man at *work* requires	5·5 oz.	of flesh-formers.
Man at *rest* „	2·0	„
Difference for *work*	3·5 oz.	„

The *horse* at work therefore consumes $\frac{27}{3·5} = 7·7$, or nearly eight times as much labour-food as the *man* at work. But what relation does the quantity of work performed by the man bear to the quantity of work performed by the horse? Mechanical physicists have estimated the work of a horse at 12,400,000 foot pounds,

and the work of a man at 1,500,000 foot pounds; therefore $\left\{\begin{array}{l}\text{the work of horse} = \\ \quad\text{,,} \quad\quad \text{man} = \end{array}\right. \dfrac{12{,}400{,}000}{1{,}500{,}000} = 8;$ or, in other words, the *work* of the horse bears the same relation to the *work* of a man that the *labour-food* of the horse bears to the *labour-food* of the man.

Let this same inquiry be extended to the labour of the ox. Dr. Playfair states that a well-fed ox gets 50 lbs. mangold-wurzel, 3 lbs. of beans, and 17 lbs. of wheaten straw per day, the whole containing 38·6 oz. of flesh-formers. The work of an ox has been estimated at 8,640,000 foot pounds.

$$\begin{array}{l}\text{Work of horse in foot pounds} = \\ \quad\text{,,} \quad \text{ox} \quad\quad\quad \text{,,} \quad\quad = \end{array} \frac{12{,}400{,}000}{8{,}640{,}000} = 1{\cdot}43;$$

that is, the work of the horse is 1·43 times that of the ox.

But the labour-food of the horse, divided by the labour-food of the ox, $= \dfrac{56{\cdot}5}{38{\cdot}6} = 1{\cdot}46.$

That is, the *labour-food* of the horse is about as many times greater than the *labour-food* of the ox as his *work* is greater than the *work* of the ox.

It is said that railway contractors practically recognize the principle of "food an exponent of work" by discharging those labourers whose appetites fail.

Food required per Day.—The *quantity* of food required per day to sustain the body of an adult in a state of health is a problem which has recently undergone considerable patient investigation. It varies greatly with age, temperature, work, &c. There are *two* modes of determining this problem with various degrees of accuracy. The *first* consists in ascertaining by careful examination and inquiry the amount of food *actually consumed* by different bodies of men of

all classes of the community under the different circumstances of labour, quietude, &c.; the *second* consists in determining accurately the amount of the various excretions, particularly *carbonic acid* and *urea.* The former is probably much the safer for *practical* guidance, the latter probably much more accurate for *scientific* purposes. For detailed information on the subject of diet the reader is referred to the able, simply written, and eminently practical treatise of Dr. E. Smith, entitled "Practical Dietary," which should be in the possession of every family man, schoolmaster, employer, and social reformer.

The following table shows some of the results of Dr. Smith's inquiries with regard to the carbon *excreted* by adults of various occupations, also the carbon *ingested* in the food eaten by the same classes. It refers to men in middle life and of full average health, size, and activity.

Carbon Excreted per Day.	
In perfect quietude . .	7·9
Middle and light labouring classes . . .	9·5
Hard labouring classes .	12·5

Carbon Consumed per Day.	
Cotton and silk operatives, stocking weavers, needlewomen, shoemakers . . .	10·5
Outdoor labouring classes	13·2

Dr. E. Smith infers that the adult body occupied in middle or light labour requires a daily *minimum* supply of food containing 9½ to 10 oz. of *carbon;* and that the ordinarily hard working classes require a *minimum* supply of carbonaceous food containing 12½ to 14 oz. of *carbon.* He estimates the quantity of *carbon* actually *consumed* per day at 25 grs. for every 1 lb. of the bodily weight. In addition to this, a portion of *carbon* from the food *escapes* by the bowel, making a total of 28 grs. of *carbon* actually required

as a *minimum* to sustain the body of an adult weighing 150 lbs. in a state of permanent health.

Dr. Smith estimates that in the case of an infant 136 grs. of *carbon* was given daily for each 1 lb. of its weight, the infant thus receiving three or four times as much *carbon* in proportion to its weight as is ordinarily supplied to an adult.

Dr. Smith, pursuing a similarly extensive course of investigations with respect to the quantities of *nitrogen* excreted *daily*, arrived at the following results:—

Nitrogen Excreted Daily.		Nitrogen Consumed in Daily Food.	
Middle and light labouring classes	about 200 grs.	Light labouring indoor classes	183 grs.
Middle and well-fed classes .	„ 260 „	Outdoor labourers in England	242 „

There is a slight discrepancy in the above quantities between the amount of nitrogen consumed and excreted, the latter being in excess, which he does not explain.

Dr. Smith infers from these data that a lightly occupied adult requires 200 grs., and an ordinarily hard-working labourer 250 grs. of *nitrogen* per day in his food.

The *nitrogen* actually *assimilated* or taken into the blood was 0·934 gr. to 1·4 gr. for each 1 lb. weight of the body. Adding to this the amount daily passed off in the refuse food, he estimates the total amount of *nitrogen* required in the food per day at 1 to 1½ grs. for each 1 lb. of the weight of the body.

The *nitrogen* required by the *infant* for each 1 lb. body weight is about six times that required by the adult.

The reader will bear in mind the distinction between

the *nitrogen* and the *nitrogenous* substances consumed, the latter being many times greater than the former.

Dr. Brinton gives the loss of *albuminous* or *nitrogenous* substances at $1\frac{2}{3}$ oz. per day, or about 1-1350th of the entire weight of the body, which must be restored by food. He also states that a new-born infant weighing 6 to 7 lbs., taking 10 to 12 oz. of milk per day, introduces about 1-270th of its total bodily mass daily.

The following table shows the quantity of *salts* required to supply the daily loss of these substances:—

QUANTITY OF SALINE CONSTITUENTS REQUIRED DAILY.

Phosphoric acid . . .	32	to	79	grs.
Chlorine	51	,,	175	,,
Sulphuric acid . . .	17	,,	41	,,
Potash	27	,,	107	,,
Soda	80	,,	171	,,
Lime	$2\frac{1}{3}$	,,	$6\frac{1}{3}$	,,
	$209\frac{1}{3}$	to	$579\frac{1}{3}$	grs.

If the chlorine and sodium be reckoned together as common salt, about 200 grs., or nearly half an ounce, is required daily. But it must be recollected that the greater portion of this substance is already contained in the food, without any further addition of the mineral itself.

Water can scarcely, in the accepted sense of the term, be considered *food*, since in all probability the water entering into the *chemical composition* of the tissues is derived from the water *chemically combined* with the *food*, yet it is an indispensable accompaniment of most ordinary kinds of food. The quantity retained in the body varies with exercise, temperature, &c. It is retained in the body in much larger quantities during rest than during activity; and the great reduction in the bulk of the body which occurs during a

course of training for a pedestrian race, or a pugilistic contest, is due to the loss of this fluid. Water is the essential vehicle by which the food is *conveyed into* the system, and by which the waste materials are *removed out* of it. The quantity of water required to supply the *daily* wants of the system, under conditions of moderate exertion and temperature, is estimated at about 6 lbs., or nearly 5 pints.

Dr. Playfair, who has devoted much labour and ability to the determination of the nature and physiological value of food, has considered this question under four heads :—

(1.) The amount of food necessary for mere subsistence *without exercise.*

(2.) The amount of food necessary for complete health with *moderate exercise* of from 5 to 7 miles daily.

(3.) The amount of food necessary for *active work*, such as is represented by a man daily walking 20 miles continuously.

(4.) The amount of food necessary for labourers with very *arduous occupations*, as navvies engaged on railways.

He calculated the first, or *mean subsistence diet*, from the dietaries of needlewomen, prisoners, cotton operatives during the cotton famine, &c. ; the second, or *moderately active subsistence* diet, was calculated from the rations consumed by ordinary soldiers in the *time of peace;* the third, or *active working* diet, he ascertained from the mean of the rations of the soldiers of several nations consumed during *time of war;* the last, or *extra hard-working* diet, he ascertained from the rations consumed by English *navvies*, blacksmiths, &c.

The following table by Prof. Playfair gives the results of these calculations :—

	Sub-sistence Diet.	Diet in Quietude.	Diet of Adult in Full Health.	Diet of Active Labourers.	Diet of Hard-worked Labourers.
	oz.	oz.	oz.	oz.	oz.
Flesh-formers	2·0	2·5	4·2	5·5	6·5
Fat . .	0·5	1·0	1·8	2·5	2·5
Starch .	12·0	12·0	18·7	20·0	20·0
Starch equivt.	13·2	14·4	22·0	26·0	26·0
Carbon .	6·7	7·4	11·9	13·7	14·3

A *prize-fighter* in training, who walked 17 miles daily for exercise, consumed the following :—

Flesh-formers . . .	9·8	oz.
Fat	3·1	,,
Starch	3·27	,,
Starch equivalent . . .	10·70	,,

Definition of Food.—Simple as it may appear, and clear as our notions respecting food may be, it is by no means easy to give an exact and *scientific* definition of the term. Popular opinion divides nutriment into *food* and *drink;* physiologically speaking there is *no* such distinction; *both* kinds of nutriment are *food.* Water and other *innutritious* fluids, however, may be described as drink, and not food. Notwithstanding objections which may be raised against it, *food* may be defined, with sufficient accuracy for all practical or scientific objects, as consisting of all those nutritious substances which are taken into the alimentary canal from the exterior of the body for the purpose of being digested.

Classification of Food. — Food is classified, according to its nature and functions, under three divisions, viz. :—1. *Plastic* or *nitrogenous* food, which

builds up, repairs, and nourishes the tissues. 2. *Respiratory* or *fuel food*, which sustains the animal heat. 3. *Mineral food*, consisting of minute quantities of the alkaline and earthy salts.

The following table shows the different kinds of food and their principal varieties :—

Food.	Inorganic		Water.	
			Salts.	
	Organic .	**Plastic** .	Albumen .	Contains oxygen, hydrogen, carbon, and nitrogen.
			Fibrin . .	
			Casein . .	
			Gelatin (?) .	
			Gluten . .	
			Legumin .	
		Respiratory .	Oleaginous: Fats, Oils	Contains carbon, hydrogen, oxygen.
			Saccharine .	
			Starchy .	

Plastic Food (from Gr., *plasso*, I form), so called because it affords the material out of which all the *tissues* are *originally* formed, and by which they are *subsequently* repaired and nourished. It is also termed *flesh-forming*, *azotized*, *nitrogenous*, or *albuminous* food. This kind of food has been described as exclusively consisting of *true nutriment*, but there can be but little doubt that some of the elements of the tissues are also derived from the *carbonaceous* or *heat-forming* food.

All vegetables contain more or less of these flesh-forming principles ; a few of them, as peas and beans, contain them in very great abundance, but in a form comparatively indigestible to human beings. The principal *plastic* constituents of flesh meat are *albumen*, *fibrin*, and *gelatin* (it is doubtful whether the latter exists in *uncooked* meat ; its nutritive value is also open to discussion) ; of bread, *gluten;* of peas and beans, *legumin.* Milk is generally regarded as a *model* food,

containing all the various constituents of the food necessary to perfect nutrition, viz., the *plastic*, the *oleaginous*, the *saccharine*, and the *saline* principles. The *plastic* element in milk is casein; the respiratory elements consist of fat (butter) and sugar of milk. It also contains phosphate of lime and other salts necessary to the formation of bone and other tissues.

The following tables by Dr. Brinton show the composition of human and cows' milk:—

HUMAN MILK.

Water				88
Solids	Flesh-formers, **Casein**		3·5	12
	Heat-givers	5·0 Sugar 3·3 Butter	8·3	
	Salts		·2	
				100

COWS' MILK.

Water				86
Solids	Flesh-formers, **Casein**		5·5	14·2
	Heat-givers	3·5 Sugar 4·5 Butter	8·0	
	Salts		·7	
				100·2

It will be seen from the above tables that *cows'* milk contains *less water* and *sugar of milk*, but *more butter:* to make it approximate in composition to that of human milk, for use in the nursery, it therefore requires to be *diluted* with water, and *sweetened* by the addition of sugar of milk.

COMPOSITION OF FLESH MEAT (BEEF).

Water				50
Flesh-formers	Fibrin and Albumen 8 *Gelatin* (?) 7	15	Solids	50
Heat-givers	Fat	30		
Mineral matter	(Salts)	5		
				100

One-half of ordinary *uncooked* beef, as is seen from the table, consists of water; consequently several vegetable substances, as peas, beans, &c., which contain comparatively little water, are, bulk for bulk, or weight for weight, much richer in *plastic* food. But little importance can be attached to the quantity of *gelatin* mentioned in the table. It is doubtful whether it exists in raw meat, or in flesh in its natural state, and its properties as a *flesh-former* are still more open to suspicion. The great value of flesh meat results not so much from its richness in the *nitrogenous* or *plastic* elements as from their *easy digestibility*.

The following tables show the *proximate* chemical composition of ordinary wheaten flour, barley, oatmeal, potatoes, rye, rice, peas, and lentils :—

WHEATEN FLOUR.

Water			14·0
Flesh-formers	Gluten	12·8	14·6
	Albumen	1·8	
Heat-givers	Starch	59·7	68·1
	Sugar	5·5	
	Gum	1·7	
	Fat	1·2	
Cellulose (fibre)			1·7
Ashes			1·6
			100·0

BARLEY.

Water			14·0
Flesh-formers (Gluten)			12·8
Heat-givers	Starch	48·0	55·8
	Sugar	3·8	
	Gum	3·7	
	Fat	0·3	
Woody fibre			13·2
Ashes (mineral matter)			4·2
			100·0

OATMEAL.

Water			13·6
Flesh-formers			17·0
Heat-givers	Starch	39·7	53·8
	Sugar	5·4	
	Gum	3·0	
	Fat	5·7	
Fibre			12·6
Mineral matter			3·0
			100·0

POTATO.

Water			75·2
Flesh-formers			1·4
Heat-givers	Starch	15·5	19·3
	Sugar	3·2	
	Dextrine	0·4	
	Fat	0·2	
Fibre			3·2
Ashes			0·9
			100·0

The potato is the least nutritious (flesh-forming) plant cultivated for human food. 1 lb. of potatoes only contains 1-3rd of an oz. of flesh-formers. In Ireland a labourer is allowed 10½ lbs. daily, in addition to a large supply of buttermilk.

RYE.

Water			13·00
Flesh-formers	Gluten	10·79	13·83
	Albumen	3·04	
Heat-givers	Starch	51·14	61·14
	Gum (?)	5·31	
	Sugar	3·74	
	Fat	0·95	
Woody fibre			10·29
Mineral matter			1·74
			100·00

RICE.

Water			13·5
Flesh-former (Gluten)			6·5
Heat-givers	Starch	74·1	76·2
	Sugar	0·4	
	Gum	1·0	
	Fat	0·7	
Woody fibre			3·3
Mineral matter			0·5
			100·0

PEAS.

Water			14·1
Flesh-former (Casein or Cheese)			23·4
Heat-givers	Starch	37·0	50·0
	Sugar	2·0	
	Gum	9·0	
	Fat	2·0	
Woody fibre			10·0
Mineral matter			2·5
			100·0

LENTILS.

Water			14·0
Flesh-former (Casein)			26·0
Heat-givers	Starch	35·0	46·0
	Sugar	2·0	
	Gum	7·0	
	Fat	2·0	
Woody fibre			12·5
Mineral matter			1·5
			100·0

Peas, beans, lentils, and other *leguminous* plants, are among the most *highly nutritious* substances known; but they, especially the two former, are exceedingly indigestible. The meal of the *lentil* enters largely into

the food much advertised under the name of *Revalenta Arabica.* It is said the *red pottage* which tempted Esau to sell his birthright was made of *lentils.*

Gluten (L., glue), or *vegetable fibrin*, is the *nitrogenous* constituent of *cereal* seeds. It forms the grey, sticky, tenacious, tasteless substance which is left when flour is made into a paste, and kneaded in a fine linen bag, under a gentle stream of water, so long as the water is rendered milky. It very much resembles *birdlime.* The *white* substance washed away consists of *starch.*

Legumin is the nitrogenous principle of *beans*, *peas*, and *lentils;* if not actually identical with *casein*, or cheese, it very closely resembles it. The Chinese prepare a kind of cheese from peas.

Heat-forming, *respiratory*, *carbonaceous*, or *fuel-food* abounds in *carbon* and *hydrogen*, the combustion of which in the body develops and sustains the *animal heat.* The chief *respiratory* foods are *starch*, *sugar*, and the *fats.* In the two former the *carbon* only is burnt, the hydrogen being *already oxidized;* in the latter the *hydrogen* as well as the *carbon* is burnt; it is therefore a more powerful *respiratory* food than the former. Starch and sugar contain oxygen in the proportions in which they form water; that is, the number of atoms of oxygen and hydrogen they contain are equal. Fats contain a very large excess of *hydrogen*, and but a small proportion of *oxygen;* the *heat* developed by the combustion of equal weights of *sugar* and *fat* is therefore much greater in the case of the latter than of the former. The following formulæ indicate the atomic composition of these bodies :—

Starch, $C_{12}H_{10}O_{10}$; sugar, $C_{12}H_{11}O_{11}$; fats, $C_{10}H_9O$.

In very cold regions the quantity of *fat* consumed would scarcely be credited but for the known veracity of the authorities by whom the facts are reported. Sir John Franklin states that he tried how much fat an Esquimaux lad about 14 years of age could eat. The boy devoured 14 lbs. of tallow candles and a piece of fat pork, and would have consumed more, but Sir John felt he had already sacrificed enough from his *limited* store for the purpose of a mere experiment. A Yakut will eat 20 lbs. of flesh daily, washing it down with a quart or two of train oil; in addition to which he will also, if he can get them, devour 10 or 12 tallow candles. Admiral Saritcheff states that a Yakut, immediately after he had breakfasted, sat down and devoured 28 lbs. of thick rice porridge containing 3 lbs. of butter.

Butter possesses the general food properties of other oils and fats; in addition to which it has the property of being exceedingly palatable, which accounts for its extensive use. Its general composition is represented with sufficient accuracy for physiological purposes by the formula—($C_{10}H_9O$). Though the fats are essentially *heat-forming*, there can be but little doubt that they aid nutrition by combining with the *albuminous* principles of the blood (especially when, as in that fatal disease, consumption, they are in *excess*), thereby rendering the blood more *plastic* (increasing its tissue-forming power), and preventing the formation of *tubercle*. The powerful preventive and curative agency of *cod liver oil* in consumption is attributed to this action. Dr. E. Smith states that every child should be trained to eat fat at its meals.

Butter is described as consisting of "a solid, crystallizable, and easily fusible fat (*palmitin*); a fluid, oily substance (*olein*); and a yellow colouring matter,

besides mechanical impurities." The peculiar odour of butter is due to a fatty principle, termed *butyrin*, which is combined with the olein. *Dripping*, *lard*, and *bacon* fat may be substituted for butter by those whose means will not allow them to purchase the latter. *Treacle*, which is often used in the poorer families in place of butter, is, especially during the colder months of winter, a very inferior food substitute for it.

Stimulants are usually defined as substances which *temporarily* increase the activity or force of the system, or of a part of the system; the temporary excitement being followed by a recoil or depression of greater or less intensity, bearing proportion to the previous excitement. Dr. Anstie, in an able work recently published, shows this definition to be open to serious objection; but the limits of this little book will not allow of further reference to this interesting subject. The principal *stimulants* in ordinary use are tea, coffee, beer, wine, and spirits.

The following tables show the composition of *tea* and *coffee*:—

TEA.

Water			5·00
Flesh-formers	Theine	3·00	18·00
	Casein	15·00	
Heat-formers	*Aromatic* oil	0·75	25·75
	Sugar	3·00	
	Gum	18·00	
	Fat	4·00	
Tannic acid			26·25
Woody fibre			20·00
Mineral matter			5·00
			100·00

COFFEE.

Water			12·000
Flesh-formers	Caffeine	1·750	14·750
	Casein	13·000	
Heat-formers	*Aromatic* oil	·002	27·502
	Sugar	6·500	
	Gum	9·000	
	Fat	12·000	
Potash with peculiar acid			4·000
Woody fibre			35·048
Mineral matter			6·700
			100·000

Though it is usual to describe the constituents of *tea* and *coffee* as *flesh-formers* and *heat-formers*, it is tolerably certain that they are not digested, and therefore have no such value. The use of these substances really depends upon the palatable beverage and the refreshing *stimulus* they afford, and not upon their food-power. Their stimulating properties are *chiefly* due to the *theine* or *caffeine* and the *volatile* oil they contain. The ultimate chemical composition of *theine* is shown in the following formula:—$(C_{16}H_{10}N_4O_4 + 2A_9)$.

Some writers have attributed to tea and coffee a peculiar power of *arresting the waste* of the tissues, and making a small quantity of food go a long way; but this would seem to be quite inconsistent with their known stimulating qualities, and entirely at variance with the general physiological principle that the *activity* and *vital force* evolved by the organism is in direct relation to the *amount* of the tissues which are *disintegrated* or decomposed, and to the *waste products* evolved. Dr. E. Smith found, as the results of some of his experiments, that the use of *tea* in certain instances rather *increased* than *diminished* the amount of the daily *waste.* Upon the whole, the sparing or

very moderate use of these beverages may not be generally disadvantageous to the community with its present habits, but that the *free*, much less the *excessive*, use of them is injurious there can be no doubt.

Cocoa, which is frequently substituted for tea and coffee, however, differs greatly from them in affording an exceedingly *nutritious liquid* food in place of mere *stimulating drinks.* Its proximate chemical composition differs from that of *tea* and *coffee* principally in the large quantity of *fat* and *albumen* it contains. *Theobromine* is very similar to *theine* or *caffeine* in its chemical qualities and composition.

Cocoa.

Water			5·0
Flesh-formers	Albumen	20·0	22·0
	Theobromine	2·0	
Heat-formers	Butter	50·0	63·0
	Gum	6·0	
	Starch	7·0	
Woody fibre			4·0
Red colouring matter			2·0
Mineral matter			4·0
			100·0

The Alcoholic Stimulants, beer, wine, and spirits, are neither useful nor economical as food; they depend for their popular use on their *stimulating* properties, which are due to the *alcohol* they contain, and which vary in *degree* according to the *quantity* of alcohol present. Alcohol contains no *nitrogen*, and therefore contains no true nutriment or *flesh-forming* principle, and can add nothing to the substance of the *decaying* tissues. It was formerly classed among the *heat-forming* foods, and supposed to save the tissues by supplying the *combustion* material necessary

to the development of the *animal heat;* but it was classed among these bodies from purely *theoretical* considerations. Recent experiments tend to show that alcohol undergoes no chemical change in the body, that it does not become *oxidized* in the system, but passes out *unburnt* as *alcohol*, and therefore can neither have *developed heat* nor have *saved* the tissues. *Alcohol* is also said by some writers to *economize* the tissues by *arresting waste;* but the experiments of Dr. E. Smith show that certain kinds of *spirit* actually *increase* the waste of the system. The testimony of all the great authorities who have latterly had the opportunity of observing its effects on masses of men exposed to excessive cold or heat, or on those who are required to exert great and *continuous* mental or muscular labour, is decidedly against the use of these stimulants. The Hudson's Bay Company have excluded them from the countries over which they have control. The Government prohibited their use in the more recent *Polar* expeditions. Sir John Franklin, Sir John Ross, Captain Kennedy, and other leading *Polar* navigators speak strongly against their use in all cases of *permanent* exposure to *excessive* cold. Drs. King, Rae, Hooker, J. Robinson, and Surgeon James Donnet, the medical officers of the later Arctic or Antarctic expeditions, speak strongly against their use during such voyages, and show that their power of enabling the men to resist sudden exposure to intense cold is very much inferior to that imparted by a cup of hot *tea* or *coffee.* Equally strong testimony against their use in *hot* climates is borne by such men as Waterton the naturalist and traveller, Dr. Livingstone, Sir James Brooke (Rajah of Sarawak), Sir John Ross, General Havelock, Lord Clive, and other equally distinguished travellers, living

and deceased. The best *trainers* entirely prohibit the use of beer, wine, and spirits during the training *necessary* for the *prize-fighter*.

Beers consist of the partially fermented *infusions* of certain plants; they contain water, *alcohol*, *acetic* acid, sugar, starch, gum, *traces* of gluten, and minute quantities of certain bitter principles derived from the hop, quassia, &c. Weak beer contains 1 to 3 per cent. of alcohol, strong beer and stout 4 to 6 per cent., strong ales 8 to 10 per cent., and very old ales that have been kept many years 10 to 25 per cent.

Wines consist of the fermented *juice* of certain fruit containing sugar (*glucose*); they contain water, *alcohol*, sugar, *tartaric* acid, minute quantities of potash, and certain *aromas*. The inferior wines contain 5 to 6 per cent. of alcohol, fair light wines 10 to 15 per cent., and strong wines, as port or sherry, 15 to 25 per cent., and upwards.

Ardent Spirits are obtained by the *distillation* of wines or other fermented liquors; their distinctive flavours are due to certain *essential oils*, which are either added or developed during the process. They consist of water, *alcohol*, and *traces* of certain *essential oils*. Brandy, gin, and whiskey contain 40 to 50 per cent. of *alcohol*.

Condiments are substances taken with the food to impart relish, or *stimulate* the digestive organs. The chief condiments used in this country are salt, mustard, pepper, and ginger. They stimulate the action of the *salivary glands* and the *mucous* coat of the alimentary canal. With the exception of salt, the less these condiments are used in health the better, especially by the young. Their free use produces *artificial* thirst, and thus sometimes leads to the formation of drinking habits.

The following table, which is founded upon the results of Dr. Beaumont's experiments, is extracted from Combe's "Physiology of Digestion :"—

TABLE SHOWING THE DIGESTIBILITY OF DIFFERENT KINDS OF FOOD.

	h.	m.		h.	m.		h.	m.
Rice, boiled .	1	0	Oysters, raw	2	55	Heart, fried .	4	0
Tripe ,, .	1	0	Eggs, soft-boiled . .	3	0	Fowl, boiled	4	0
Eggs, raw .	1	30	Beefsteak, broiled .	3	0	Veal, broiled	4	0
Apples, ripe, raw. . .	1	30	Mutton, boiled . .	3	0	Beef, hard, old, salted, boiled . .	4	15
Brains, boiled	1	45	Apple dumpling, boiled	3	0	Soup, beef, vegetables, and bread .	4	0
Sago ,,	1	45	Bread, wheaten .	3	30	Soup, marrow-bones . .	4	15
Tapioca ,,	2	0	Butter, melted	3	30	Pork, salt, boiled . .	4	30
Milk ,,	2	0	Cheese, old and strong	3	30	Veal, fried .	4	30
Milk, raw .	2	15	Potatoes, boiled . .	3	30	Duck, roasted	4	30
Eggs, roasted	2	15	Eggs, hard-boiled . .	3	30	Suet, beef, roasted .	5	3
Gelatin, boiled	2	30				Pork, roasted	5	15
Potatoes, baked . .	2	30						
Custard, baked . .	2	45						
Apples, sour, raw . .	2	50						

Nutritiousness and **Digestibility,** though generally confounded in the popular estimation, are entirely different properties. Some bodies, as *cheese*, consist almost *entirely* of *nutriment*, but are exceedingly *indigestible;* others again, as *rice*, are exceedingly *digestible*, but contain comparatively *little* nutriment.

Economical Admixture of Foods. — About 300 grains of *nitrogen* and 4,600 grains of *carbon* are daily thrown out of the system by the lungs, skin, kidneys, and bowels. A well-arranged system of diet should supply these elements in very nearly their due proportion, and not compel us to take very much *more* of the one element in order that we may obtain

the *requisite* supply of the other. Hence arises the *economy* of the proper admixture of foods. If a man lived on potatoes alone, he would require at least 13 lbs. daily to supply the required *nitrogen;* if on bread, he would require 4 lbs.; while, on the other hand, if he lived on meat alone, he would require 6½ lbs. daily to supply the necessary *carbon;* whereas an admixture of 2 lbs. of bread and ¾ lb. of meat would be amply sufficient, thus *economizing* both *food* and *digestive power.*

Cooking renders the food more digestible, savoury, and palatable. It promotes its digestion principally by *gelatinizing* and rendering *soluble* the *sarcolemma* which surrounds the muscular fibre of the flesh and the cell walls which enclose the fat, and thus exposing their contents to the action of the digestive juices. This not merely lessens the labour of the digestive organs, but reduces the quantity of food actually required by lessening the amount that passes through the bowels *undigested.*

Hunger — Seat of Hunger. — The peculiar sensation or state of feeling termed *hunger* is *normally* brought about by the want of solid food or nutriment; but its precise nature, its immediate cause, and even the exact *seat* of the feeling, are unknown. Attempts have been made to determine the *seat* of hunger by the *vivisection* of animals, but the results of different experimenters have been very contradictory, and it is exceedingly doubtful whether any real knowledge on this subject can be obtained by such means. The section of the nerves of the stomach and the adjacent parts in all probability produces sufficient injury, from mere *nervous shock*, to paralyze their *normal* action.

When the feeling of hunger is but *moderate*, it constitutes pleasurable *appetite;* but when very power-

ful it manifests itself in a strong sense of gnawing, amounting even to pain, and a feeling of *emptiness* and *sinking* in the region of the stomach. These sensations are accompanied by general faintness, nausea, giddiness, and the secretion of gases in the stomach. If the feeling of *hunger* be not now allayed by attention to the wants of the system, the body begins to *feed* upon *itself;* the *lymphatics* absorb the *tissues*, which are appropriated as temporary nutriment; the body rapidly emaciates and loses all its powers; even the sense of hunger disappears, to be followed by a perfect *loathing* for all food, mania and delirium in all probability supervening, until at last death kindly relieves the sufferer. (See "Starvation.")

The peculiar sensations consequent on hunger would seem to refer it to the *stomach;* also the fact that in the *normal* condition of the body the feeling disappears on the introduction of food, or even indigestible and innutritious substances. It is well known that some savage and half-civilized races are in the habit of introducing clay, sawdust, and other similar *innutritious* substances into the stomach to allay the cravings of hunger. Its pangs are thus probably somewhat allayed, but the sense of emptiness and the faintness arising from want of food remain.

Hunger has been variously attributed by different physiologists to the following causes :—

(1.) *Emptiness* of the stomach.

(2.) The *irritation* of the *coats* of the stomach by the *gastric juice.*

(3.) To the *distension* of the stomach *follicles* by the *gastric* juice.

(4.) The *wants* of the system.

(5.) The *capillary* condition of the coats of the stomach.

(6.) The *subjective* feeling consequent on the state of the brain and nervous system. Dr. Mayo states that a person may be hungry without a stomach and thirsty without a throat.

But it cannot result from *emptiness* of the stomach alone, since the stomach is frequently *empty*, even for days together, as in certain cases of fever, without our experiencing the sensation of hunger; and in certain diseases of the *pylorus* and *mesenteric* glands the stomach may be crammed full of food and the person be ravenously hungry.

Neither is it probably due to irritation caused by the action of the *gastric juice*, since there is every reason to believe that it is *not* secreted *unless* food be present; and if it were present ready formed in the *gastric tubuli*, in sufficient quantity to produce their *distension*, it would necessarily escape through the open apertures of the tubuli into the stomach by its own pressure. Nor can hunger be *simply* due to the *wants of the system*, since in many cases of fever, where no food has been partaken of for several days, the patient does not experience the least approach to appetite; also in certain cases of insanity the patient endeavours to starve himself, the feeling of appetite or hunger being entirely absent.

Dr. Carpenter is of opinion that its *remote* cause is the *wants of the system*, which bring about a peculiar *capillary* condition of the stomach, which constitutes its *immediate* cause.

The relief afforded by food, and the effects of opium, tobacco, and other narcotics, when taken into the stomach, show that hunger is dependent on that organ.

Thirst—Seat of Thirst.—*Thirst*, like *hunger*, is a general or *systemic* sensation; that is, a state of feel-

ing brought about by the *wants* of the *system.* Its more immediate or *local* seat is the *mucous* membrane of the back of the *mouth*, the *fauces*, and the *top of the throat.* Its *normal* cause is a deficiency of fluid in the body; and it may be immediately relieved by introducing water into the system through an opening in the stomach, through the intestines, through the skin, as by immersion in a warm bath; or by injecting weak saline solutions into the veins, as in cases of Asiatic cholera. *Thirst* is also caused by introducing hot, *irritating* substances, as *spices* and alcohol, also salt, &c., into the alimentary canal. In these instances the purpose of the *thirst* is evidently to impel us to take into the system the fluid necessary for their sufficient dilution. Thirst is sometimes purely *subjective;* that is, originated by the action of the brain and nerves, as in certain diseases of the nervous system.

The symptoms of severe thirst are a sense of dryness and clamminess of the mouth and pharynx, the tongue seeming to stick to the roof of the mouth, great *nervous irritability*, and *difficulty* of *respiration.* The feeling is even more intolerable than that of *hunger*, and in hot climates, if not relieved, quickly produces madness.

A case is recorded in which a man who had cut through his œsophagus drank several bucketfuls of water daily without allaying his thirst, which continued insatiable so long as the water was allowed to pass out of the wound. When, however, a little water was injected into the stomach the thirst was speedily quenched.

The free use of tobacco, beer, spirits, &c., is eminently provocative of *artificial* thirst, especially during summer, and it would be exceedingly amusing, were it less serious, to observe the extent to which a numerous class among our summer excursionists in-

dulge in potations of "bitter beer," &c., which provoke the very thirst they are pretended to allay.

SUMMARY OF FOOD—HUNGER AND THIRST.

Food consists of substances taken into the stomach for the purpose of *digestion*, or conversion into blood.

Food is rendered necessary by the *waste* of the system.

Food is the *primary* source of *nervous* and *muscular* power.

Food which supplies *calorific* power is termed *heat-forming*, *respiratory*, *carbonaceous*, or *fuel* food, and consists of starchy, saccharine, or oleaginous bodies which contain a preponderance of *carbon*, or *carbon* and *hydrogen*.

Food which supplies *dynamical* (mechanical and mental) power is termed *histogenetic* (tissue-forming), *nitrogenous*, *azotized*, *proteinous*, or *albuminous*, and consists of substances which are comparatively rich in *nitrogen*, as milk, eggs, flesh, cheese, peas, beans, and other bodies containing *fibrin*, *albumen*, *casein*, or *gluten*.

A small portion of the *respiratory* food also probably contributes to the formation of the *tissues;* and likewise a portion of *histogenetic* or albuminous food to the development of the animal heat.

The student and the hard-labouring *professional* man require even more *histogenetic* or tissue-forming food than the ordinary *physical* labourer.

A due supply of *animal* food is necessary to the development of a *high civilization;* that is, to the development of races who are capable of *sustained muscular and mental* labour.

Alcohol, either strong or dilute, cannot possess any *histogenetic* power from its *deficiency* of *nitrogen;* and,

as far as the results of modern experiments can show, is neither *oxidized* nor *burnt* in the *system*, and therefore is probably neither a *heat-former* nor a *flesh-former*. It is consequently deficient in true food-power, or, in other words, can neither *nourish* the body nor develop *heat*.

A due mixture of *heat-forming* and *flesh-forming* food is most beneficial, economizing both *food* and *digestive* (vital or nervous) power.

An excess of *animal* food is much more injurious than a corresponding excess of vegetable food.

Cooking renders food more savoury, wholesome, and digestible, and destroys the parasitic animals which might otherwise excite serious if not fatal disease; saves food, and enables the same amount of *digestive* (vital) power to do more effective work.

Hunger and *thirst* are peculiar sensations respectively due to the *general* wants of the *system*. The former manifests itself *locally* in the stomach, and arises from a *deficiency* of *nutriment;* while the latter manifests itself *locally* in the region of the *fauces*, and is consequent on a *deficiency* of *fluid* in the system.

THE BLOOD.

Blood.—The blood is the *nutritive* fluid contained in the *veins* and *arteries*, out of which the various *tissues* are built up, repaired, and renovated, and by which the various organs receive the *vital stimulus* which enables them to perform their respective *functions*. It is popularly described as a bright *scarlet* fluid; but this is only partially true, one-half of the blood in the body being of a dark *purplish* colour. This mistake has arisen from the fact that the dark purple blood, which cannot be seen *in* the body, immediately changes

from its dark purple hue to a bright scarlet colour when it escapes from the veins and comes into *contact* with the *oxygen* of the air. The blood has been beautifully described as the "river of life." Its excessive loss produces death by *syncope*, or fainting. After the blood has been drawn from the body it *coagulates*—that is, *spontaneously* separates into a *clear* liquid and a *red* gelatinous mass. It is slightly *viscid*, has a saltish taste, and a peculiar faint odour resembling that of the perspiration. This odour is said to be rendered more intense by the addition of sulphuric acid. To the naked eye blood is apparently *homogeneous*. *Arterial* blood is of a *bright red* colour. *Venous* blood is of a *dark* or *purplish* red, by reflected light, but when a thin layer is held up and viewed by *transmitted* light it appears of a *greenish* colour; it is therefore said to be *dichromatic*. The specific gravity of blood is about 1055.

The Quantity of Blood contained in the body of an adult man is not known with any degree of accuracy, though many attempts to determine it have been made by the ablest physiologists. It has been variously estimated at from 12 to 28 lbs. Weber estimates it at 11 to 15 lbs.; Valentine at 28 lbs. Harvey estimated it at 1-20th of the entire weight of the body; Haller at 1-5th. It is more generally estimated at about 1-12th to 1-10th of the weight of the body. Many unexpected difficulties arise in attempting to solve this physiological problem. For instance, a considerable quantity of blood always remains in the body, particularly in the head, after the most complete bleeding possible. The quantity of blood that can be drawn from a fasting animal is scarcely more than half of what may be drawn from an animal after a full meal. In addition to these difficulties there is every

reason to believe that when an animal is bled to death very slowly a considerable quantity of other fluids may be absorbed into the bloodvessels, thus adding to the apparent quantity of the blood discharged.

A female who died from sudden hæmorrhage lost 26 lbs. of blood; a plethoric female decapitated in France lost 24 lbs. The following are two of the methods which have been adopted with the object of determining the quantity of blood still retained in the system. In each case the blood remaining in the body after the most complete bleeding possible is washed out by the repeated injection of water into the bloodvessels; but according to the one method the water is evaporated, and the quantity of blood it contains estimated by the *weight* of the solid residue. According to the other the quantity of blood washed out of the vessels is determined by the *depth* of the *colour* of its solution as compared with a standard solution of blood. This is termed the *chromatic* method. The body of the animal is then finely minced and infused, and the quantity of blood contained in the infusion determined by the same (chromatic) method. The weight of the blood discharged, *plus* the weight of the blood *washed* out of the *vessels*, *plus* the weight of the blood *washed* out of the *minced flesh*, give the total weight of the blood originally contained in the body. By another, Vierordt's method, the total quantity is estimated by multiplying the quantity of blood expelled by each contraction of the left ventricle, by the number of times it contracts during the time the blood takes to circulate once round the body. He estimates the quantity of blood passed through the ventricle at each contraction as 6·3 oz., and the number of contractions or beats during one circulation at 27·7, which gives

about 11 lbs. avoirdupois of blood in the adult body. It would be impossible to enter fully into such investigations within the limits of an elementary treatise such as this, but it was felt desirable to indicate to the reader the nature of the difficulties which attend all fundamental investigations, even when they appear most simple, and to show him the means by which, through the ingenuity, ability, and perseverance of the noble science army of truth-explorers of all nations, these difficulties are overcome, and the exquisite and wonderful means by which the great Artificer of the universe accomplishes His ends are laid open for our admiration and guidance.

Structural Character of the Blood.—Human blood, when viewed by the naked eye, appears to be a simple and perfectly *homogeneous* red fluid; but when observed with a high magnifying power it loses this homogeneity of appearance, and is seen to consist of myriads of distinct microscopic structures, the *red*

Fig. 22.—HUMAN BLOOD CORPUSCLES.

A. When freshly drawn, *a*, as seen on the flat; *b*, as seen edgewise; *, three-quarter view.
B. Forming *rouleaus*, by adhering on their flat surfaces like piles of coin.
C. As altered by exposure to air, &c.
D. A lymph globule, or colourless blood corpuscle.

and *white corpuscles* floating in a clear, transparent fluid, termed the *serum*.

Composition of the Blood.—The chemical composition of the blood varies with the age, sex, and

constitution of the individual, also at different periods in the same individual, according to the state of health, exercise, time after meal, &c. Repeated bleeding also greatly alters the composition of the blood, producing a great diminution in the number of *red corpuscles*, and a corresponding increase in the quantity of the *serum*, or fluid portion. The blood of men contains a *greater* number of *red corpuscles* and *less* water than that of women.

1,000 parts of blood contain about 500 parts of *liquor sanguinis* and 500 parts of *moist corpuscles.*

The following table indicates the average composition of each 1,000 parts of the blood of a man, according to the analyses of Becquerel and Rodier :—

COMPOSITION OF HUMAN BLOOD.

Water				779·0
Solids	Corpuscles	Hæmatin	7	141·0
		Globulin	134	
	Fibrin			2·2
	Albumen			69·4
	Fatty matters	Serolin	0·2	1·6
		Phosphorized fat	0·49	
		Cholesterin	0·09	
		Saponified fat	1·00	
	Extractive matters			6·8
				1000·0

Salts in the blood	Chloride of sodium	3·10
	Tribasic phosphate of soda	0·20
	Phosphates of lime and magnesia	0·33
	Other soluble salts	2·30
	Metallic iron	0·57
		6·50

The composition of 1,000 parts of human blood may be expressed with sufficient accuracy in round

numbers as follows:—*Water*, 780; *globulin*, 140; *albumen*, 70; *fibrin*, 2; *fatty* matters, $1\frac{1}{2}$; *extractives*, $6\frac{1}{2}$.

Playfair gives the following formula as indicating the general chemical composition of *blood* and *muscle*:—($C_{45}H_{39}N_6O_{15}$).

1,000 parts of **Red Corpuscles** contain—

Water			688
Solids	Hæmatin (including iron)	16·75	312
	Globulin and cell membrane	282·22	
	Fat	2·31	
	Extractive matters	2·60	
	Mineral substances (exclusive of iron)	8·12	
			1000

1,000 parts of **Liquor Sanguinis** contain—

Water			902·9
Solids	Albumen	78·84	97·1
	Fibrin	4·05	
	Fat	1·72	
	Extractives	3·94	
	Mineral substances	8·55	
			1000·0

The following table shows the plan of the composition of *fluid* blood as it *circulates* in the vessels:—

Blood	Liquor sanguinis	Fibrin. Albumen. Salts. Water.
	Corpuscles (*suspended* in liquor sanguinis)	Red. White.

Red Corpuscles.—The red corpuscles of human blood consist of exceedingly minute, pale reddish yellow, circular, *biconcave* discs, with rounded edges. They were formerly regarded as nucleated cells, the little depressions or hollows in their upper and lower

surfaces producing by their optical or refractive effects the appearance of dark central spots or *nuclei*. Their specific gravity is about 1088. Each *corpuscle* has the form of a double concave lens, such as those used in the construction of the spectacles of short-sighted persons. These cells are now regarded as non-nucleated. Should you possess a microscope, or have access to one, prick your finger with a very fine needle, place the minute drop which exudes and adheres to the point of the needle under the microscope, covering it with a very thin piece of glass or a piece of talc to keep it from the air; look at it carefully, and you will observe all the appearances shown in the diagram. (See Fig. 22.) These corpuscles exhibit, when not in circulation, a strong tendency to arrange themselves in little *piles* or *rouleaus*. Their appearance changes with, and is therefore partly dependent upon, the *medium* or liquid in which they float; when moistened with a drop of water they swell, become round or globular, and ultimately burst. In other liquids of different densities they acquire other forms and appearances. From this circumstance they were formerly described by different observers as little globular cells, &c., and have been variously termed *blood-cells*, *blood-corpuscles*, *blood-discs*, and *blood-globules*. In human blood they are *circular*, and vary from 1-4,000th to 1-2,800th inch in diameter, their average *diameter* being about the 1-3,200th inch. Their average *thickness* is about 1-12,400th of an inch, or about *one quarter* of their diameter. Some idea of the minuteness, and of the immense multitude of these corpuscles may be gathered from the fact that it is estimated that one cubic inch of freshly drawn, healthy human blood contains about 84,000,000 of *red* corpuscles and 240,000 *white* or *colourless* corpuscles. Dr. Draper estimates that 20,000,000 red corpuscles

cease to exist at each beat of the heart, or, in other words, about 20,000,000 red corpuscles die every second of time.

The *blood corpuscles* of the *mammalia* are in general *circular;* in some animals they are more minute than in man, as in the case of the musk-deer, whose corpuscles do not exceed 1-12,000th inch in diameter. The *red corpuscles* in the blood of reptiles are in general *oval*, *nucleated*, and comparatively large.

In the case of suspected murder a practised and skilful anatomical microscopist can readily distinguish *human* blood stains from *red paint* or *red stains;* also from the blood stains of most other animals, by the *shape*, *size*, and general *microscopic* character of the adhering red corpuscles. The blood of the *mollusca* does not contain *red corpuscles*.

Structure of the Red Corpuscles.—A red corpuscle most probably consists of a delicate *cell-wall* enclosing a homogeneous, semi-fluid substance. Wharton Jones and other physiologists, however, contend that the *red corpuscle* has no *cell-wall*, but is homogeneous throughout, and that it is most probably the *nucleus* of a former cell which only existed during the earlier stages of its being. The latter view is, however, less generally accepted than the former. The reader is advised to carefully peruse the section towards the end of the volume on "Cells and Cell Development."

The *red corpuscles* are composed of *two* proximate chemical principles—*globulin* and *hæmatin* (the red colouring principle of blood),—the properties and composition of which have been previously described.

Functions of the Red Corpuscles.—The red corpuscles absorb oxygen, which they *carry* to and *distribute* through the *tissues* of the various organs,

developing and *stimulating* their *vital activity;* hence they have been termed *oxygen carriers.* Blood deprived of its corpuscles will only *dissolve* 1-13th of the quantity of *oxygen* it will dissolve in its natural state. The *red corpuscles* do not themselves pass out of the *capillaries*, and cannot reach the *tissues;* but they give up the dissolved oxygen, which passes through the *walls* of the capillaries to the *tissues* by the action of *osmosis.* In *anæmic* (from Gr., *an*, not, and *aima*, the blood) diseases—that is, in diseases arising from an excessive *deficiency* of the *red corpuscles* of the blood—a most marked incapacity for even moderately sustained *muscular* or *mental* exertion is manifested. A sufficient supply of *oxygen* to sustain the *vital activity* of the *muscular* and *nervous* tissues cannot be furnished to them because of the *deficiency* of the necessary *vehicles*—the *oxygen carriers* or red corpuscles. Medicinal preparations of iron are found to exert a most beneficial influence in these diseases by *promoting* and *increasing* the development of these *corpuscles.* The number of red corpuscles suffers a very rapid diminution after repeated bleeding.

A second function they perform is the *secretion* or *elaboration* of the *hæmatin;* this function may, however, be regarded as subordinate to the first. Doubtless they perform other important functions which have hitherto escaped the inquiries of the physiologist.

Development and Decay of the Red Corpuscles.—The red corpuscles are generally supposed to originate from the *lymph* or *chyle* corpuscles, which develop into the coloured blood corpuscles. The red corpuscle, having performed its functions, dies, degenerates like other tissues, and liquefies. It was formerly thought that the red corpuscle gave birth

to new ones of the same kind, but this view is now generally discarded.

The White or Colourless Corpuscles of the blood are contained in the blood of all animals, the *invertebrata* included. (See D, Fig. 22.)

They are minute, *globular*, transparent, or slightly pearly, colourless, *nucleated* bodies, about the same size or a little larger than the *red corpuscles*. Their surface presents a peculiar roughened appearance. They consist of a very delicate external *cell-wall*, enclosing a *nucleus*, a *nucleolus*, and *granular* matter. These parts are rendered more distinct by the action of dilute acetic acid, which dissolves the granular matter. The *white corpuscles* of the blood are also a little larger than the *lymph* corpuscles, which contain no *cell-wall;* they are about the 1-2,500th inch in diameter. In healthy human blood the *white* corpuscles are in the proportion of about 1 to 300 of the *red* corpuscles; but their number varies to a certain extent, according to the time of the day at which the experiment is made, being invariably greater *after* than before a meal.

In certain diseases, as in **Leucocythemia** (from Gr., *leukos*, white, and *kutos*, a cell, and *aima*, blood), they amount to 1 in 7 of the red corpuscles. They are more numerous relatively in women and children than in men, and in the *lower* than in the higher animals. As we pass down in the scale of animals the number of *red* cells gradually *decreases* until they at last disappear entirely from the blood of the lower animals, which contains only *white* corpuscles.

Their proximate chemical composition is unknown, since they always separate with the *fibrin* of the blood: some physiologists consider their composition *identical* with that of *fibrin*.

Functions.—The functions of the *white* corpuscles have not been certainly determined, but Dr. Carpenter and most modern physiologists regard one of their principal functions to be the *development* of the *fibrin* of the blood, or the conversion of the *albuminous* substances of that fluid into *fibrin*, which is regarded as the principal "*plastic*" and *true nutrient* compound of the blood. Another function which is attributed to the *white* corpuscle is the perfecting and development of its *nucleus*, which ultimately becomes a *red corpuscle*. The history of the *white corpuscle* is very interesting to the physiologist, and will, when fully ascertained, definitely determine the problem as to which ranks *higher* in the grade of organization—*albumen* or *fibrin*.

The Liquor Sanguinis (from L., *sanguis*, blood) **or Blood Plasma** (from Gr., *plasso*, I form) is the clear, colourless liquid in which the *red* and *white* corpuscles float. It consists chiefly of an *alkaline* solution of *albumen* and *fibrin* mixed with dilute solutions of other salts, as chloride of sodium, tribasic phosphate of soda, &c. It also contains a small but varying proportion of fat.

Functions of the Liquor Sanguinis.—The liquor sanguinis serves as the medium by which the *red corpuscles* or *oxygen-carriers* are floated through the *vascular* system, and supplies the *plastic* or *nutrient* materials necessary to the *development* and *repair* of the tissues. (See "Nutrition" and "Repair.")

The Vital Properties of the Blood are its power of *coagulation*, also, probably, a certain amount of *formative* and *self-maintaining* power, and a limited capacity of self-purification through the elimination of morbid or even mineral poisons, as in certain fevers,

&c. The *vital* properties of the blood probably reside in its *fibrin* and *corpuscles*.

Coagulation of the Blood (from L., *coagulo*, I curdle).—When healthy human blood drawn from the body into a cup or basin is left to itself it gradually *coagulates*, or separates into *two* portions—an upper *liquid* portion, termed the *serum*, and a lower *gelatinous* substance of greater or less firmness, termed the *cruor*, *clot*, or *crassamentum*. Coagulation usually commences in from three to five minutes after the blood is withdrawn from the body, the clot continuing to contract for ten or twelve hours subsequently.

During coagulation the whole of the blood at first assumes a *gelatinous* appearance; then as the *clot* contracts drops of *serous* fluid gradually begin to ooze out. These drops slowly increase in number and quantity, unite, and cover the gelatinous clot with a layer of straw-coloured liquid; this layer, which consists of *serum*, becomes deeper and more abundant as it is squeezed out by the gradual contraction and hardening of the *crassamentum* or *clot*.

The following table shows the composition of blood *after* coagulation :—

Coagulated Blood	Serum	Albumen.
		Salts.
		Water.
	Clot	Fibrin.
		White corpuscles.
		Red ,,

When a very thin slice of the *clot* is examined by the aid of a microscope it is seen to consist of a *network* of white fibres enclosing *corpuscles* in its *meshes*. If the clot be washed in a stream of water the corpuscles are washed out, and the *white fibrous network* alone remains.

The Serum (from L., *serum*, whey) is the colourless or pale straw-coloured, greasy, viscid, *albuminous* fluid which separates from the *clot* during *coagulation.* It consists of the *liquor sanguinis* deprived of its *fibrin.* When heated to 160° Fah. or upwards it coagulates, a small quantity of *uncoagulable* liquid, termed the *serosity*, exuding during the process.

The Serosity (from L., *serum*, whey) is the thin, aqueous, *saline* solution which remains after the separation of the *albumen* from the *serum* by the process of *coagulation.* It consists of water holding the *salts* of the *serum* in solution.

The Cruor, Crassamentum, or Clot is the more or less firm, *gelatinous*, dark red substance which separates from the blood during the process of *coagulation.* It consists of *fibrin* and the red and white *blood corpuscles*, the fibrin having *spontaneously* assumed the form of a network, enclosing the corpuscles within its meshes. When the blood coagulates very *slowly*, or there is a *deficiency* of the red corpuscles, the *upper* part of the *clot* is of a *yellowish white* colour.

The Cause of Coagulation is at present unknown, and is the subject of much interesting discussion among physiologists. Dr. Richardson attributes the coagulation of the blood to the escape of *ammonia.* He shows that when blood is drawn from the body it evolves *ammonia* prior to, or during the process of coagulation; that whatever prevents the escape of the *ammonia* prevents or retards its coagulation; also that the addition of 1 part of *ammonia* to 3,000 of blood will cause it to retain its *fluidity.* The more striking phenomena of coagulation are due to the *spontaneous* solidification or *fibrillation* of the fibrin; but the real question at issue is, What causes this spontaneous coagulation? Dr. Richardson's theory explains it by

assuming that its state of *liquidity* in the system is due to the presence of *ammonia*, and that its subsequent coagulation is due to its escape. Some physiologists regard coagulation as a *vital* process, while others regard it as the *death* of the blood. Coagulation is *accelerated* or *retarded* by various influences, as shown in the following table:—

Accelerate Coagulation.	Retard Coagulation.
The contact of *solids*.	Contact with the living walls of the bloodvessels.
The contact of morbid or decaying organic substances, as *pus*.	
Exposure to air.	Exclusion from the air.
Rest.	Motion.
Moderate warmth.	Heat above 150° or below 32° Fah.
Flowing in a *slow* stream.	Flowing in a *rapid* stream.
Shallow vessels.	Deep vessels.
	Certain neutral salts, as nitrate of potash.
	Certain poisons, as opium, belladonna, and prussic acid.
	Death by hanging, drowning, and the respiration of certain gases, as carbonic oxide and coal gas.
	Death by certain diseases, as typhoid fever.

In cases of murder attempts are sometimes made to disguise the mode in which the crime has been effected by inflicting wounds in the throat or other parts of the body after death; but this ruse will not deceive the physiologist; *living* blood only coagulates. Hence if there is clot, the wound was inflicted during *life;* if, on the contrary, there is no clot, the wound was inflicted *after* death.

The cessation of bleeding, internal or external, and

the adhesion of the opposite surfaces of incised wounds, is consequent on the coagulation of the blood.

John Hunter, the celebrated surgeon and founder of the Museum of the College of Surgeons, stated the blood would not coagulate in consequence of the destruction of its *vital* principle in cases of death by lightning, from over-fatigue, as in animals hunted to death, from violent mental emotion, the passions, or in cases of death produced by violent blows on the epigastrium. This statement is, however, said to be contradicted by more recent experience.

Buffy Coat — Cupped Appearance of the Blood.—In certain cases of disease the *upper* portion of the *clot*, to the depth of half an inch or so, is of a *yellowish white* or *buff* colour; this constitutes the *buffy coat* of the blood. The *surface* of the *clot* is always slightly *concave*, but when the thickness of the buffy coat is considerable it undergoes considerable elaboration, slowly contracting and drawing up the outer edges of the clot, so as to give it a *hollow* or *cupped* appearance.

The *buffy coat* of the blood was formerly attributed solely to an excess of *fibrin*, and was supposed to be owing to an *inflammatory* state of the blood; and many a poor-blooded patient has been sent to his grave by being bled through this error on the part of his physician, since it frequently results from quite the opposite condition of the blood, viz., a *deficiency* of the blood corpuscles.

It may be caused—1, by *excess* of *fibrin*, which causes the blood to coagulate more slowly, so that the corpuscles descend to the bottom of the vessel, and separate more completely; 2, by the *liquor sanguinis* being very thin from *deficiency* of *fibrin*, so that the

corpuscles readily sink through it; 3, by *deficiency* of the *red corpuscles* themselves in relation to the fibrin. The tendency of the *corpuscles* to aggregate into little piles or masses also favours the formation of the *buffy coat.*

Gases in the Blood.—The *living* blood always contains *oxygen*, *nitrogen*, and *carbonic acid* gases; also traces of *ammonia.* 100 vols. of human blood contain about 16 vols. of oxygen, 1½ of nitrogen, and 29 of carbonic acid, in a *free* or uncombined state—that is, simply dissolved in, but not *chemically* combined with the blood.

CIRCULATION AND THE ORGANS OF CIRCULATION.

Every *thought* we think, every *movement*, however slight, we perform, though but the moving of a finger or an eyelid, is attended with the destruction or waste of the *nervous*, *muscular*, and other tissues, just as every ray of *light* or *heat* which is emitted from the *burning* candle is attended by the combustion and consequent destruction of its particles. These *tissues* therefore require incessant *repair* and *renovation.* Even during the period of sleep, when we are in the state of most perfect bodily and mental repose, numerous *physical*, *chemical*, and *vital* actions pursue an unceasing round, producing an equally incessant course of *waste* and *decay*, and necessitating the operation through the whole system of an equally continuous *counter*-process of *nutrition* and *repair.* Not only is it necessary that the *tissues* in the various parts of the body should be sufficiently and continuously *nourished;* but it is equally necessary that they, and more especially the *nervous* and *muscular* tissues,

should be supplied with the *stimulus* of *oxygen*, otherwise they would be entirely unable to perform their *functions*. The regular and continued *supply* of *nutritive* material and of *oxygen* to every part of the living body, and the immediate *removal* of the *disintegrated* or *waste* tissues is effected through the process of *circulation*.

Circulation is the process by which the blood or *nutritive* fluid is carried out from, and returned to the *heart* from the various parts of the body.

The Organs of Circulation are the heart, the arteries, the veins, and the capillaries. (See Figs. 8, 12, 18, 23, 24, 25, 26, 27, and 30.)

The Heart, which acts as a sort of *force-pump*, and is the principal organ of *circulation*, consists of a

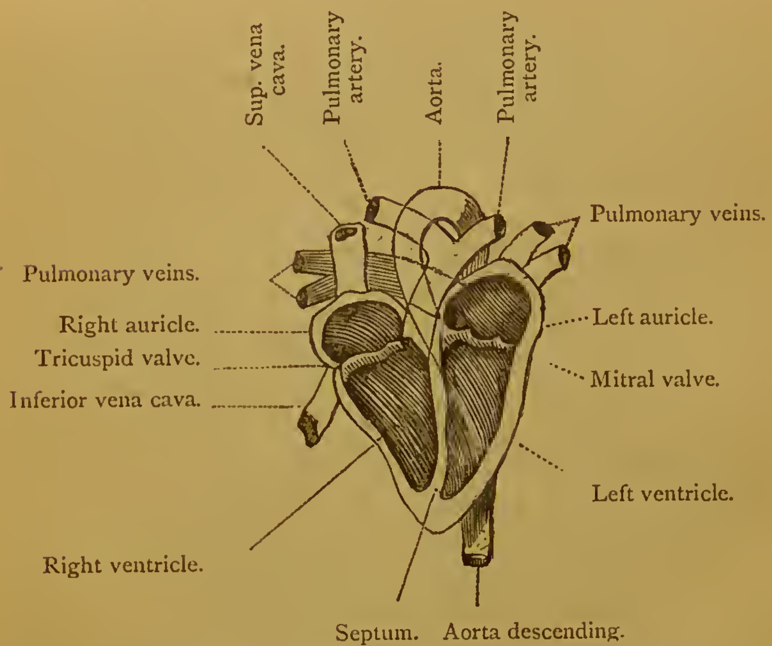


Fig. 23.—Theoretical Section of the Human Heart.

hollow conical *muscular bag*, which is connected with the principal bloodvessels. (See Figs. 8, 24, and 30.) It contains four *cavities* or *chambers*, the walls of which *dilate* and *contract* independently of the will.

It is *situated* in the centre of the *thorax* between the lungs, and on a level with the lower 2-3rds of the sternum, lying obliquely forward and to the left. Its lower end or apex beats against the walls of the chest in the space between the fifth and sixth ribs, between two and three inches to the left of the sternum, where its action can be most distinctly felt.

The heart of an adult man is about 5 inches long, $3\frac{1}{2}$ inches broad, and $2\frac{1}{2}$ inches thick, or about the size of a man's fist, and weighs 10 to 12 ounces. It continues to increase in size till late in life.

Pericardium (from Gr., *peri*, round, and *kardia*, the heart).—The heart is suspended by the large vessels which proceed from its summit within a *fibro-serous* bag or sac termed the *pericardium*. This membrane, like the rest of the *serous* membranes, consists of a *closed* sac, one portion of which is *reflected*, or as it were tucked into the other. The *reflected* portion adheres to and invests the heart, forming its proper tunic. Inflammation of this membrane is termed *pericarditis*. The general arrangement of this membrane resembles that of the *pleura*. (See "Pleura," also "Serous Membranes.")

Structure of the Heart.—The heart is composed of *striated* muscular fibre. It contains two *upper* cavities termed *auricles*, and two *lower* cavities or chambers termed *ventricles*. The two auricles are separated by a *septum*, or dividing wall, termed the *septum auriculorum*. The two ventricles are also separated by a partition termed the *septum ventriculorum*. The right auricle communicates with the right ventricle, and the

left auricle with the left ventricle, by openings termed respectively the right and left *auriculo-ventricular* openings, but the right and left sides of the heart do not communicate directly with each other. Each of these openings is surrounded by a fibrous ring termed the *zona annularis*, and is furnished with a *valve* to prevent the return of the blood. (See Figs. 23 and 24.) The *tricuspid valve* prevents the blood from passing backward from the *right* ventricle to the right auricle; the

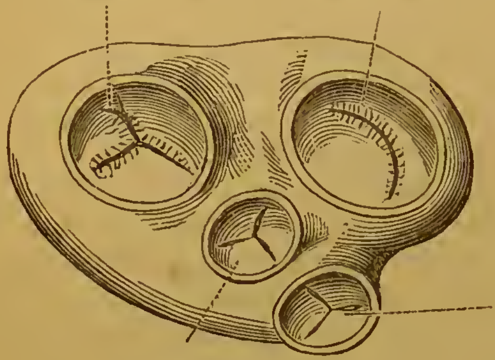


Fig. 24.—Upper Surface of the Heart, the Auricles having been Dissected away to show the Valves.

bicuspid or *mitral* valve in the *left* side of the heart prevents the blood from passing backward from the left ventricle to the left auricle. The *valves* are composed of *serous* and *fibrous* membrane; they are attached at their *lower* extremities to the walls of the heart by little *tendinous* cords termed *cordæ tendineæ;* otherwise they would flap through into the auricles, offering no resistance to the return of the blood. The inside walls of the heart are covered with little *fleshy* columns termed *carneæ columnæ*, which stand solidly out from their sides. Some of these fleshy columns

are attached to the walls at their base only, their upper extremities being attached to the *cordæ tendineæ* of the valves only; these are termed *columnæ papillares* or papillary columns. They probably regulate the action of the tendinous cords and the valves. These structures may be readily observed by examining the interior of a sheep's heart.

The *right auricle* communicates with the upper *vena cava* by an opening which is *not* guarded by any *valve*, the weight of the descending column of blood acting as a substitute for a valve; and with the lower *vena cava* by an orifice guarded by three *semilunar* folds, forming the *Eustachian valve*. The *right ventricle* communicates with the *pulmonary artery*, the orifice of the artery being guarded by the *pulmonary valve*, also consisting of three semilunar folds. The *left* auricle communicates by four orifices, having no valves, with the four *pulmonary veins;* the *left ventricle* communicating with the *aorta*, its orifice being guarded by the *aortic valve*, which consists of three semilunar folds.

The heart is *nourished* by blood supplied by the two *coronary* arteries which leave the *aorta* immediately above the *aortic* valve.

The Nerves of the heart are derived from branches of the *pneumogastric* nerve; it is also well supplied with nerves from the sympathetic system, in addition to which it is furnished with small *ganglia*.

The heart of reptiles contains *three* chambers only, viz., *one* ventricle and two auricles, a part of the venous blood only passing to the lungs to be aërated. The heart of fishes is still more simple, containing but *two* cavities, an auricle and a ventricle.

Action of the Heart.—The heart pursues an unwearied and unceasing round of exertion, alternately *contracting* and *dilating* from the first moment of ex-

istence to the latest period in life. It has been calculated that the heart *beats* some 3,000,000,000 times and *propels* some 500,000 tons of blood through its *chambers* in the course of an ordinary life. The venous blood passes (see Figs. 23 and 25)—1, from the *venæ*

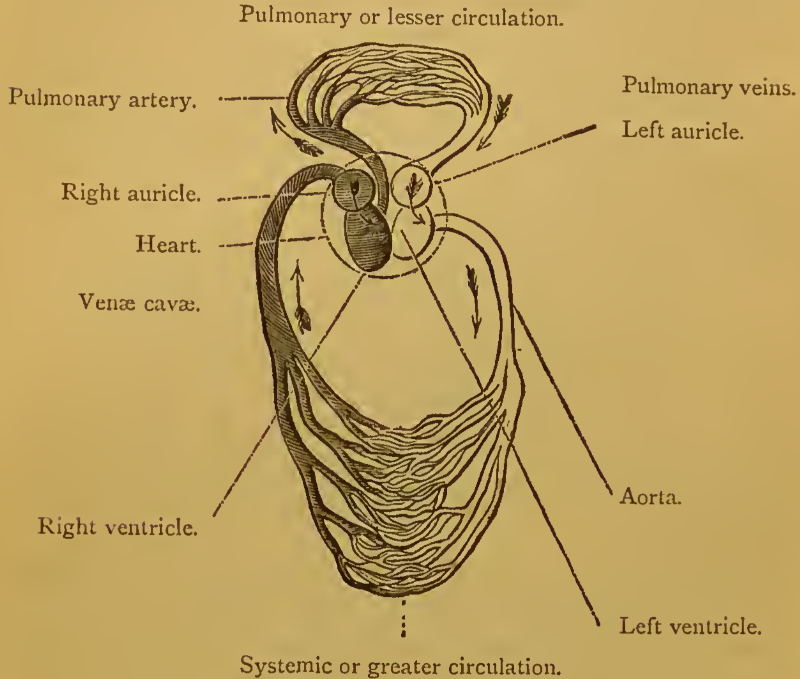


Fig. 25.—Theoretical Diagram of Circulation of Man and the Mammalia.

cavæ into the *right auricle;* 2, the right auricle *contracts* and *propels* the blood forward to the *right ventricle*, which *dilates* to receive it, the *tricuspid valve* opening meanwhile; 3, the right ventricle then *contracts* (the tricuspid valve closing) and *drives* the blood through the *pulmonary artery* into the *lungs*, where it is *aërated*, without which change it cannot return to the heart; 4, the *aërated*, revitalized blood returns by the four pulmonary veins to the *left auricle*, which

contracts and *drives* the blood into the *left ventricle*, the *mitral valve* opening and the ventricle dilating to receive it; 5, the left ventricle now *contracts*, driving the blood through the *aorta* into the system, its *regurgitation* being prevented by the closing of the *aortic valve*.

Greater, Lesser, and Portal Circulation.—It will thus be observed that the heart is the centre of two processes of *circulation*—the one termed the *lesser* pulmonary or *respiratory* circulation, whose object is the *aëration* of the blood; the other the *greater* or *systemic* circulation, whose object is the nutrition and stimulation of the entire organism. The process by which the *liver* is supplied with *venous* blood from the organs of digestion for the elaboration of the *bile* is termed the *portal* circulation.

Systole (from Gr., *sustello*, I contract).—The two auricles *contract* simultaneously, their contraction being termed their *systole*. The ventricles also contract simultaneously, their *systole* commencing just as that of the auricles is terminating. The heart contracts with a force of about 4½ lbs. on the square inch, and sends out 3 to 4 oz. of blood at each contraction.

Diastole (from Gr., *dia*, apart, and *stello*, I send).—The auricles *dilate* simultaneously, also the ventricles, this action being termed their *diastole*. The diastole of the ventricles also commences just as that of the auricles terminates.

Sounds of the Heart.—If the ear be applied to the chest immediately over the region of the heart two distinct sounds will be perceived. The *first* is a prolonged dull sound, which has been compared to the articulation of the word *lubb* or *loobb;* this is followed by an interval of *silence;* at the termination of this interval the *second*, a shorter and sharper sound, which has been compared to the articulation of the syllable

dup, is heard. The exact cause of these sounds is still subject of discussion among physiologists. By means of the *stethoscope* the physician can distinctly hear the sounds in the interior of the heart, and thus ascertain, by the working of its valves, &c., its condition of health or disease.

Course of the Blood.—The blood leaving the *left* side of the heart, as previously described, passes out by the *aorta*, or principal *artery*, into the general arterial system, by which it is conveyed to the capillaries, which distribute it through the tissues; it is then collected by the veins and returned to the *right* side of the heart by the *venæ cavæ.*

TABULAR VIEW OF THE COURSE OF THE BLOOD.

	Arteries.		Veins.
To the Lungs	2 pulmonary arteries.	*From the* Lungs	4 pulmonary veins.
Head	Carotid arteries.	Head	Jugular veins, venæ innominatæ, and superior vena cava.
Upper extremities	Aorta, subclavian, axillary, brachial, ulnar, radial, palmar, and digital arteries.	Lower extremities	Digital, plantar, tibial, popliteal, femoral, and saphenous veins.
Trunk and its viscera	Aorta, intercostal, and abdominal arteries; cœliac axis; gastric, hepatic, and splenic arteries; superior and inferior mesenteric, and common, external, and internal iliac arteries.	Trunk and its viscera	Common, external, and internal iliac veins; mesenteric, splenic, gastric, portal, abdominal, and intercostal veins, and inferior vena cava.
Lower extremities	Femoral, popliteal, peroneal, back and front tibial, plantar, and digital arteries.	Upper extremities	Digital, palmar, ulnar, radial, brachial, axillary, and subclavian veins; venæ innominatæ, and superior vena cava.

The principal arteries and veins only are given in the above table.

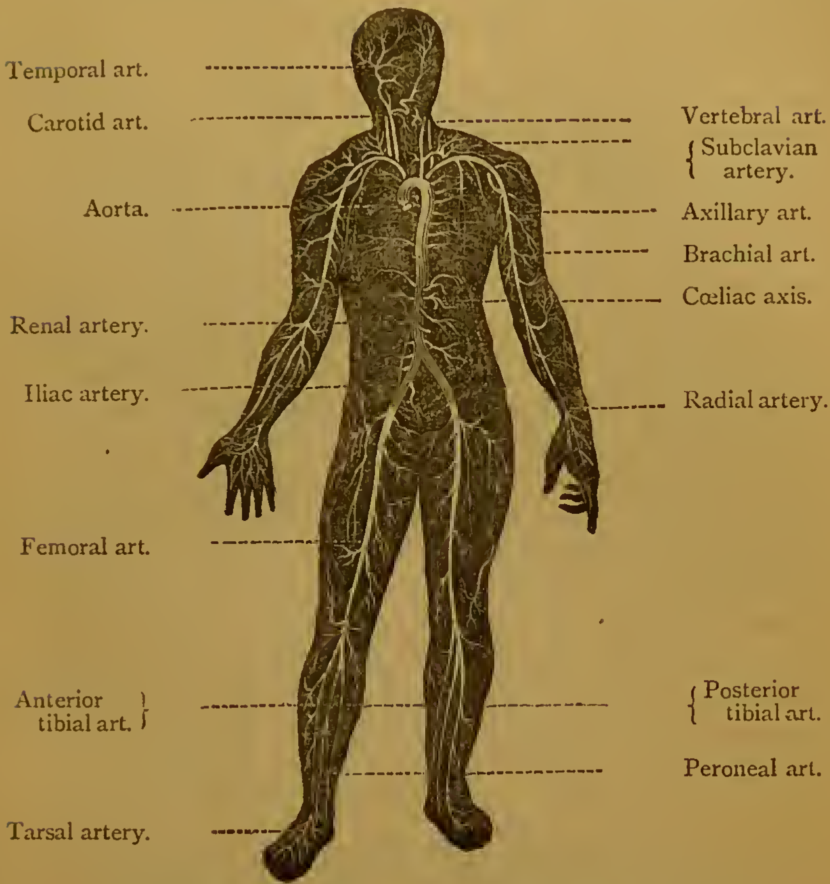


Fig. 26.—THEORETICAL DIAGRAM OF THE ARTERIAL SYSTEM OF MAN.

The arteries, with the exception of the *pulmonary* arteries, contain pure bright *red* blood, which is therefore generally termed arterial blood. The walls of the arteries consist of three coats :—

(1.) An *external* tough whitish coat of *areolar tissue.*

(2.) A *middle* elastic coat, composed of yellow *elastic fibrous* tissue and *unstriped muscular* fibre ; in the larger arteries there is more elastic tissue, in the smaller more muscular fibre.

(3.) An *inner* elastic and *epithelial* coat, consisting of *fenestrated elastic* membrane, lined with *fusiform* or spindle-shaped scaly *epithelium cells.*

The Arteries (from Gr., *aer*, air, and *tereo*, I keep) were supposed by the ancients to contain *air* because they were usually found *empty* after death. They are cylindrical, tough, elastic, flexible tubes, which receive the pure *aërated* blood from the heart, and *carry* it out and *distribute* it to the capillaries, which diffuse it through the various glands and tissues for the purposes of *nutrition* and *secretion*. (See Fig. 26.)

If an artery be violently torn, as when a limb is pulled off by machinery, the ends of the arteries curl inwards, stopping the aperture of the torn artery, and preventing the escape of the blood, so that sometimes scarcely a drop is lost from the larger vessels. The *aorta*, or principal artery of man, is nearly an inch in diameter; that of the whale is said to be upwards of three feet in diameter.

The arteries *commence* in the heart, and *terminate* in the capillaries. The walls of the arteries are nourished by blood supplied by minute arteries termed *vasa vasorum*, which enter and ramify in their structure. They are also supplied with nerves from the sympathetic system.

Anastomosis of the Arteries and Veins.—The arteries and veins *anastomose* (from Gr., *ana*, through, and *stoma*, a mouth), divide, open into, and communicate very freely with each other, as seen in the veins at the back of the hand. If a ligature be tied round one of the principal arteries of a limb, so as to obstruct the passage of the blood, the *temperature* of the limb will fall considerably; but after a time the limb will again become *warm*, showing that the circulation has become re-established through the medium of the *other branches* of the *tied* artery.

The Pulse, or beating of the arteries, which may be felt most conveniently at the wrist, is caused by

the contraction of the heart. Medical men examine the *pulse* to ascertain the rate of movement of the heart. The *rapidity* of the *pulse* increases with exertion or excitement, is greater when standing than sitting, and when sitting than lying down, and becomes exceedingly rapid during fever. The following table shows the rates of pulsation at different periods of life :—

In the	infant,	130	to	140	per minute.
„	adult,	70	„	80	„
„	aged,	50	„	60	„

It is said by some that in *advanced* age there is a general increase in the *rapidity* of the pulse.

The *pulse* is caused by the sudden *extension* or *elongation* of the extensible, elastic artery by the sudden propulsion of fresh blood into it by the heart's contraction. Its *elasticity* causes it immediately to contract or shorten to its original dimensions, again to be distended by a fresh propulsion of blood and a new pulsation, the phenomenon being repeated while life endures.

Movement of the Blood in the Arteries.— It has been calculated that the blood moves through the arteries at the rate of twelve inches per second, and makes the entire circuit of the body in about thirty seconds. It moves more rapidly during youth, diminishing in velocity as age advances. The rapidity of the circulation is increased by *muscular* and *mental* exertion, and under the excitement of the passions and the emotions.

Wounded Artery. — A wounded *artery* may readily be distinguished from a *vein* by the bright *red* colour of the blood which issues from it, and by

the force, rapidity, and *jerking* of the current. When an artery is wounded, a small stone or other hard body should be placed over the artery immediately *before* the wound, and *between* it and the heart. A handkerchief or cord should then be tied over the stone, just *above* the wound, and twisted very tightly, by inserting a piece of stick and twisting the same in the handkerchief, so as to compress the part immediately before the wound and *between it and the heart*, the object being to stop the flow of the blood which moves *from* the heart *to* the wound. It is useless to *tie* a wounded artery *beyond* the wound, since the blood flows directly *from* the wound *to* it, and does *not return* by the arteries. By attention to this simple expedient, many lives which would otherwise be lost might be saved.

A *wounded vein* should be tied on the *opposite* side of the wound—that is, just *beyond* the wound,—since in the *veins* the blood flows *to* the heart.

The Capillaries (from L., *capillus*, a hair) are microscopic cylindrical tubes varying from 1-4,700th to 1-1,000th inch in diameter, which receive the blood from the arteries and distribute it through the tissues. They consist of an extremely delicate homogeneous membrane containing embedded nuclei. The largest capillaries are invested with fine longitudinal and transverse elastic fibres, and approximate in structure to the arteries and veins.

The smaller capillaries do not admit of the passage of the *red corpuscles*. The *liquor sanguinis* exudes or passes through the walls of the capillaries by *osmosis* into the surrounding tissues, and *nourishes* them. The blood moves through the capillaries with uniform velocity.

The sectional area of the capillaries has been

estimated at 400 times that of the arteries; the blood therefore moves through them with 400 times *less* velocity than through the arteries, or at the rate of $1\frac{3}{4}$ inches per minute.

A. Small vein large enough to admit several blood-globules abreast.
B, B'. Capillaries admitting but a single series of blood corpuscles.
C, C'. Epithelium cells covering skin.

Fig. 27.—Network of Capillaries.

Portion of web of frog's foot magnified.

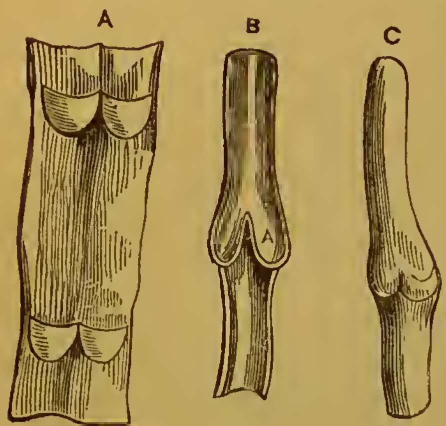
The Veins, or bloodvessels which return the blood from the capillaries to the heart, correspond in general structure and arrangement to the arteries. With the exception of the *pulmonary* veins, they contain impure, dark, *venous* blood. They commence in small twigs, formed by the junction of the capillaries; these twigs join together, until, after repeated junctions, they form the larger veins, these again ultimately uniting to form the *vena cava*, or principal trunk vein, which pours the blood into the heart.

The veins are larger and more numerous than the arteries; but the walls of the former are thinner and

more transparent than those of the latter, as seen in the veins at the back of the hand, which permit of the colour of the dark venous blood showing through.

The veins, like the arteries, contain three coats; they differ from the arteries principally in the greater *thinness* of the *middle* elastic coat. They are described as *deep*, *superficial*, and *sinuses* (as found in the skull). They *commence* in the capillaries and terminate in the heart. The veins are nourished by blood supplied by the *vasa vasorum*. The movement of the blood is *slower* in the veins than in the arteries.

The Valves of the veins, shown in Fig. 28, A, B, C, consist of pocket-shaped or semilunar folds of



A. Vein slit open, showing pocket-shaped valves.
B. Valves closed by pressure of blood from behind.
C. Outside of vein, showing expansion over the seat of a valve.

Fig. 28.—Semilunar Valves.

fibrous membrane and epithelium from the inner coat of the vein. These valves are so arranged that when the blood attempts to pass backward the membranous folds of which they are composed become distended, press against each other, and close the passage, thus preventing the regurgitation of the blood. Fig. 29 shows the action of these valves.

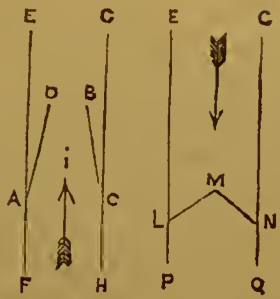


Fig. 29.—PLAN SHOWING THE ACTION OF THE VALVES OF VEINS.

1. The valves *open*, to allow of the blood passing toward the heart; A D, and C B, the valves; E F, and G H, the sides of the vessel; I, the central channel.
2. The valves *closed* by the pressure of the blood from behind; E P, and G Q, the sides of the vein; L M, and N M, the valves. The arrows indicate the direction of the currents.

Forces of the Circulation.—The chief forces which develop and maintain the circulation are,—

(1.) The contractile force of the heart. This has been termed the *primum mobile* (main spring) of the circulation; it is also designated a "*vis à tergo*" (force from behind, or pushing force).
(2.) The contractibility of the arteries.
(3.) The muscular compression of the veins produced by exercise. During exercise the veins are compressed, and a portion of their contents expelled; this portion can only move forward in the direction of the heart, because of the obstruction of the valves.
(4.) A *selective* force, sometimes termed a *capillary* force, due to the attraction of the tissues or the glands for the constituents of the blood. In the lower animals the *capillary* circulation is probably maintained almost entirely by this force, which has been termed a "*vis à fronte*" (force in advance).

The Circulatory System has been compared to a **Hot Water Warming Apparatus.** Let a *long* tube or pipe be attached to the *upper* part of a boiler, and carried up through the higher stories of a house, and having passed round the rooms, be bent so as to pass down again and re-enter the lower part of the boiler. If the *whole* apparatus be now filled with water, and heat be applied to the boiler, the contained water will be immediately put into circulation; the heated water, passing up through the *ascending* tube to the upper stories, parting with its heat, and thus warming the rooms, then returning by the *descending* pipe, will re-enter the boiler, again to become heated and repeat its circuitous, heat-conveying journey. Apparatus fitted up on this principle is frequently applied to the warming of houses.

In comparing these movements with those of the circulatory system, the *boiler* is supposed to represent the *heart*, the *ascending* tube the *arteries*, and the *descending* tube, which returns the water to the boiler, the *veins*.

The forces which cause these *circulatory* movements are, however, entirely unlike, the movement of the *water* being effected by the *expansive* agency of the *heat*, that of the *blood* by the *mechanical* propulsion of the *heart*.

The *arterial* blood which is sent out through the system is, however, both *warmer* and possessed of a greater *capacity for heat*. During its conversion into *venous* blood its temperature and its *capacity for heat* are reduced, and it therefore parts with both *latent* and *sensible* heat, thereby warming the adjacent parts, and therein so far imitating the action of the hot water warming apparatus.

RESPIRATION AND ORGANS OF RESPIRATION.

Respiration is the process by which the dark *venous* blood is purified by being brought into contact with the *oxygen* of the air. *Carbonic acid* gas, *watery vapour*, and *organic* matter are *excreted* during the process.

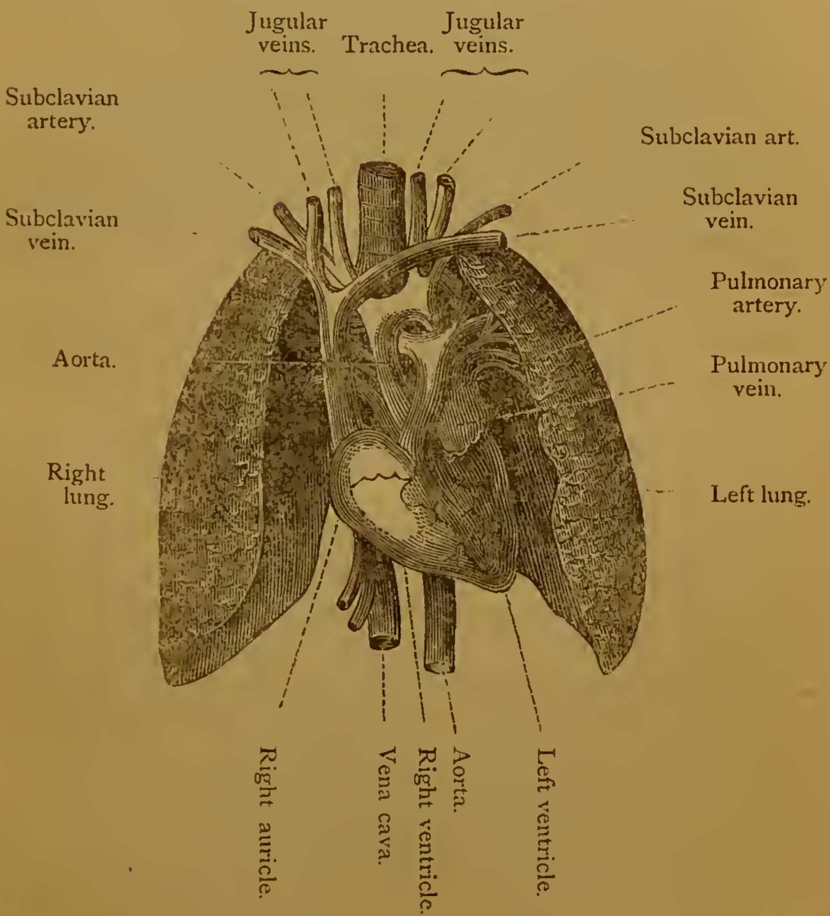


Fig. 30.—Lungs, Heart, and Principal Bloodvessels of Man.

The Lungs.—The principal seat of this process in the higher animals is the *lungs* (see Figs. 8, 30, and 35), which consist of an arrangement by which a very *large surface* of blood is exposed, through the medium of a very *thin membrane* (not more than 1-1,000th of an inch in thickness), to a *very extensive surface* of air.

EXPERIMENT I.—Breathe on to the surface of a bright mirror; it immediately becomes covered with minute drops of *water*, showing that *watery* vapour is evolved from the lungs in breathing.

EXPERIMENT II.—Breathe through *lime* water for a few seconds, taking care to prolong the expiration as much as possible after each breath. The solution will become quite *white* and *turbid*, showing that *carbonic acid gas* has been expired during the process of breathing out.

EXPERIMENT III.—If the breath be passed gently for a short time through strong oil of vitriol, the vitriol becomes blackened, thus proving the presence of organic matter in the breath. No young or inexperienced student should perform this dangerous experiment.

Changes in Expired Air.—From the above experiments it will be seen that the *expired* air contains considerable quantities of *carbonic acid* and *watery vapour;* also traces of *organic* matter, which are exceedingly prone to putrefaction. *Respired* air is also said to contain *traces* of *ammonia* and *hydrogen.* Though *respired* air is rendered impure and injurious by the *presence* of these impurities, yet it is rendered far more deleterious by the *simultaneous* removal of the oxygen.

COMPOSITION OF ATMOSPHERIC AIR.

	Pure.	Respired.
Oxygen . . .	20·61	16·26
Nitrogen . .	77·95	77·95
Carbonic acid .	0·04	4·39
Aqueous vapour .	1·40	1·40
	100·00	100·00

The above table presumes that the quantity of watery vapour remains unchanged, which is not the case. The actual quantity of the carbonic acid and watery vapour evolved during respiration varies very greatly with temperature, exercise, health, &c. Dr. Smith found an increase of two cubic inches of carbonic acid per minute for every 1 lb. weight carried by a soldier in marching order.

Changes in the Blood by Respiration.—When the *blood enters* the *lungs* it is of a dark *purplish* colour, very *impure*, quite unfitted for the *repair* of the tissues or the support of life, and highly charged with *carbonic acid* gas. When it *leaves* the *lungs* it has assumed a bright *scarlet* colour, has parted with most of its *carbonic acid*, has absorbed a large quantity of *oxygen*, and acquired power to *repair* the wasted tissues and to *stimulate* and *sustain* the various processes of life. In other words, respired or *aërated* blood has lost *carbonic acid*, become highly *oxygenized*, and acquired powerful *reparatory* and *vivifying* properties.

The principal agents in the absorption of oxygen are the *blood corpuscles*, which have therefore been designated *oxygen-carriers* (page 175).

The Change of Colour in the blood has been ascribed by Liebig to the presence of *iron* in this fluid. He supposes it to be present in the *venous* blood in

the form of *protocarbonate* of iron. When this substance is exposed to the action of the air in the lungs he assumes that it is decomposed into *protoxide* of iron and *carbonic acid gas*, the latter being evolved during respiration ; while the *protoxide* of iron, combining with an additional quantity of *oxygen*, is converted into *sesquioxide* of iron, which communicates to *arterial* blood its characteristic *bright scarlet* colour. This theory is not now so generally received as formerly.

Other theorists, however, basing their researches on *microscopical* investigations, attribute these changes of colour to *physical* alterations in the corpuscle itself. The *dark* blood corpuscles in *venous* blood have been observed to be *thicker* and more *globular*, to have *thinner* and more *transparent* walls, and to be able to *transmit* light more freely than the bright red corpuscles of arterial blood.

The red corpuscles of arterial blood are, on the contrary, *thinner*, more *discoidal*, *biconcave*, have *thicker* walls, and *reflect* the light more readily, to which fact the *brighter* colour of arterial blood is now more generally attributed.

The *oxygen* and the *carbonic acid* gas, which are always present in both *venous* and *arterial* blood, are supposed to be held in solution in a *free* or uncombined state, and not, excepting in minute proportion, to be *chemically* united with those fluids.

Source of the Carbonic Acid.—The carbonic acid is not formed *in* the *lungs*, as was formerly supposed, but most probably in the *interstices* of the tissues throughout the whole of the organism. The greater part of the *oxygen* absorbed during respiration is probably absorbed by the *red corpuscles* of the blood, and carried by them to every part of the system. Then, passing through their walls by *osmosis*, it enters the

interstitial spaces in the tissues, and there *meets* and *combines* with the *carbon* of the partially *disintegrated* or *wasted* tissues, producing *carbonic acid.*

The oxygen *before* combination, and the *carbonic acid* the *result* of that combination, are both supposed to be held in *solution* in the *intercellular fluid* which more or less abundantly pervades all the living tissues.

The oxygen dissolved in the *arterial* blood is supposed to pass through the walls of the capillaries by the action of *exosmose*, while the carbonic acid produced by the combination of the oxygen with the carbon of the *waste* tissues passes *into* the capillaries by the process of *endosmose.* The arterial blood, thus *losing* most of its oxygen, and *receiving* much carbonic acid, is converted into *venous* blood, and returned to the lungs to be repurified and revitalized.

A portion of the carbonic acid evolved during respiration is, however, supposed to be formed by the direct combination of the respired *oxygen* with *carbon* contained *in* the *blood*, this carbon being derived from the *food* and not from the *tissues.*

Reasons for the above Theory.—1. Place a frog, or other animal not readily suffocated, in a glass receiver filled with *nitrogen*, or any other *respirable* gas *not* containing *oxygen.* If the gas respired by the frog be analyzed at various intervals, it will be found that as much carbonic acid has been expired by the frog as it would have expired had it been duly supplied with atmospheric air. Hence, in the absence of oxygen to combine with the carbon, the carbonic acid, if present, must have previously existed already formed in the blood. Hence the carbonic acid is not *formed* in but *excreted* by the lungs.

2. If *oxygen*, *nitrogen*, and some other gases be passed through *venous* blood drawn from any part of

the body, *carbonic acid* gas will be evolved. Hence *venous* blood is charged with *carbonic acid before* it reaches the lungs.

3. When oxygen unites chemically with *carbon*, *hydrogen*, or any other elementary substance, much *heat* is evolved. Hence if these bodies entered into combination solely, or even principally, in the lungs, these organs would become *much hotter* than other parts of the body. But this is not the case, the temperature of all parts of the body being *nearly* uniform. Hence the temperature produced by these combinations being nearly uniform all through the body, the probability is that these chemical combinations also take place throughout the tissues of the living organism.

Mechanical and Physical Respiration.—Having explained the *nature* and *objects* of respiration as a *vital* process, it becomes necessary to describe the *mechanical agents* by which this process is effected. The principal *mechanical* agents by which respiration is effected are the *thorax* and the *lungs*.

Structure and Movements of the Thorax.—The *thorax*, or chest, consists of an airtight box, with *moveable* walls and flooring, containing but one opening. When these walls recede from each other the chest is enlarged *laterally* in every direction. When its floor is depressed it is enlarged *vertically*. By the combination of these two movements, *lateral* and *perpendicular*, its internal capacity is greatly enlarged or reduced. When the chest is enlarging, air rushes in by virtue of *atmospheric pressure*; this constitutes *inspiration*. When it is contracting air is expelled; the latter constitutes *expiration*.

The *thorax*, or chest, which is somewhat of the form of a beehive, is situated in the upper part of the trunk, extending from the shoulders to the bottom of

the lowest rib. It is formed of the 12 dorsal *vertebræ*, 24 *costæ* or ribs, with their cartilaginous appendages, and the *sternum* or breast-bone. These together form an open cage or framework, giving strength and resistance to the whole structure. The *spaces* between the

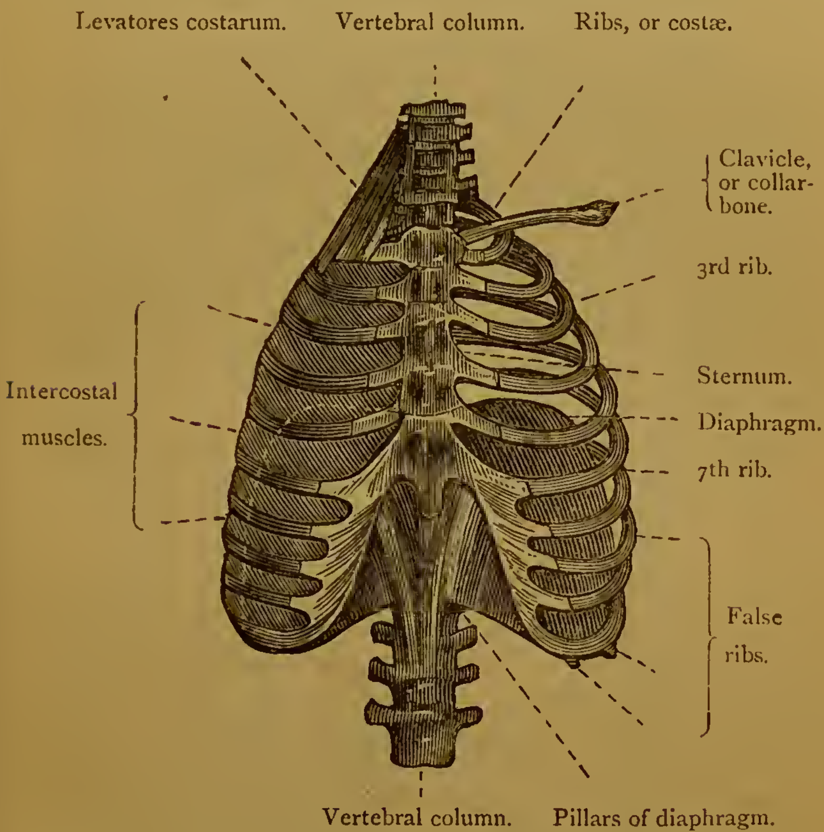


Fig. 31.—THE THORAX WITH ITS PRINCIPAL MUSCLES.

ribs or *costæ* (*intercostal spaces*) are filled up by the *intercostal muscles;* these, together with the bony framework, form unbroken walls, constituting the sides or walls of the thorax. The *floor* of the thorax is formed by the *diaphragm* (see Figs. 8 and 31), a large,

thin, membranous *muscle*, which stretches across the lower part of the *thorax*, separating it from the *abdomen*, of which it constitutes the *roof*, thus dividing the *trunk* into two parts. This muscle, the *diaphragm*, is attached in *front* to the *sternum* or breast-bone, *behind* to the *vertebral column*, and on *every side* to the lower ribs. It is arched, hemispherical, or *dome*-shaped, being *convex* above and *concave* below. Its attachments to the vertebral column, ribs, and sternum are all airtight; but it is *perforated* to admit of the passage of the *alimentary* canal, *bloodvessels*, *nerves*, &c., to the abdomen. Its junctions with these walls, and with the canals, tubes, &c., which pass through it, are also airtight. It is *tendinous* at its centre, and when it contracts *flattens* out so as to *press* the contents of the abdomen downwards and outwards, and thus to *enlarge* the cavity of the chest.

Movements of Respiration.—**Inspiration,** or the drawing in of air by the lungs, is caused by the *lateral*, *vertical*, and *antero-posterior* enlargement of the cavity of the chest, the air rushing in through the windpipe to fill what would otherwise form a partial vacuum. The *ribs*—which, for the sake of illustration, may be considered to be so many parallel bars—are attached by their heads to the vertebral column, so as to

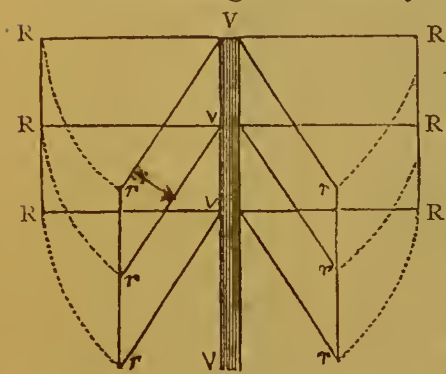


Fig. 32.—Plan of Portion of Back of Thorax.

form with it a *double obliquity*, or inclination, viz., a *lateral* and an *antero-posterior* obliquity, respectively shown by Figs. 32 and 33.

Let the parallel *oblique* lines, marked *r* V (Fig. 32), represent a *back* view of three pairs of ribs in the position of repose—that is, inclined *laterally* to the vertebral column V V. When the *levatores costarum* (elevators of the ribs) and the *intercostal* muscles (see Fig. 31) contract they raise the ribs to a nearly *horizontal* position, represented by the lines R V, the end (*r*) of each rib describing an *arc*, represented by the dotted line. In this latter position it will be seen that the ends, R R, of the ribs are removed to a greater distance from the back-bone and from each other; the cavity of the chest is therefore enlarged *laterally*.

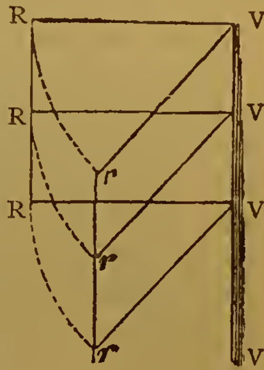


Fig. 33.—PLAN OF PORTION OF SIDE OF THORAX.

Let the parallel *oblique* lines, marked *r* V (Fig. 33), represent a *side* view of three ribs inclined *antero-posteriorly* (front to back) to the vertebral column V V. When the ribs are brought to a nearly *horizontal* position, as viewed from *front to back*, they are represented by the lines marked R V, the ends (R R R) being removed to a greater distance from the back-bone, V V. In this case the distance from the *front to the back* of the chest is increased, or, in other words, the cavity of the chest is enlarged *antero-posteriorly*.

But simultaneously with the *lateral* and *antero-posterior* enlargement of the chest the *diaphragm* (see Fig. 31), which forms its floor, *descends*, thus increasing its vertical height; hence all *three* dimensions of the chest are *simultaneously* increased. The air, therefore, forced by its external pressure, rushes in to fill the additional space thus obtained.

Popular opinion, transposing cause and effect,

erroneously attributes the *enlargement* of the chest to the *inrush* of the air, whereas the enlargement of the chest is the *cause* of the influx of the air which constitutes *inspiration.*

These movements, with the consequent *thoracic* enlargements, may readily be observed by placing the hands on the *sides* and on the *front* and *back* of the chest while breathing. They very much resemble those of a *pair of bellows:* when the sides of the bellows are separated, air rushes in; this corresponds with the process of *inspiration:* when they are pressed together, the air is forced out; this corresponds with *expiration.*

The following simple calculation will show that a small increase in the respective dimensions of the chest will produce a considerable increase in its cubical capacity:—Let it be supposed that the length, breadth, and height of a cubical box 6 inches in diameter were increased 1-3rd, then the ratio of the cubical capacity of the former to the latter would be as $6 \times 6 \times 6$ is to $8 \times 8 \times 8$, or as 216 c. i. are to 512 c. i.

Expiration, or the expulsion of the air from the *lungs,* is effected by the *compression of the lungs,* caused by the closing in of the *diaphragm* and *walls* of the chest. The *diaphragm* relaxes and is pushed up by the *abdominal viscera,* which are pressed in by the contraction of the muscles of the abdomen; the *ribs* and *sternum* fall forwards and inwards under the influence of gravity and the elasticity of the *costal cartilages* and ligaments. The *internal intercostal* and the *abdominal* muscles also assist in this movement. Probably also the organic muscular fibre in the walls of the cells, by its contractibility, assists in the expulsion of the air from the lung sacs.

Muscles of Respiration.—The principal muscles of ordinary *inspiration* are the external intercostals, a portion of the internal intercostals, the levatores cos-

tarum, a portion of the triangulis sterni, and the diaphragm. In forced inspiration all the muscles of the back and neck which act upon the ribs and sternum assist, as the serratus, latissimus dorsi, pectorals, sterno-mastoid, &c.

The principal muscles of ordinary *expiration* are a portion of the internal intercostals, the infracostal and the abdominal muscles, and a portion of the triangulis sterni. In forced expiration the longissimus dorsi, the sacro-lumbalis, &c., also act.

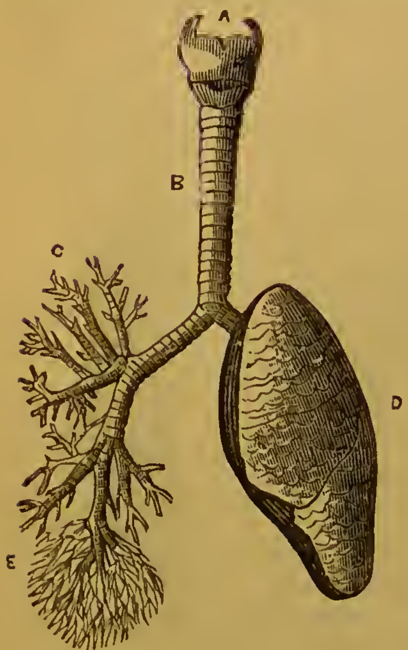
Pectoral and Abdominal Respiration. — Respiration effected through the movements of the chest is described as *pectoral* or *costo-superior;* that effected through the movements of the diaphragm and the abdominal walls is termed *abdominal* respiration. The former predominates in females, as seen in the movements of the chest in singers; the latter in man. The diagram (Fig. 34) illustrates both these movements (antero-posteriorly), the plain black line showing those of *ordinary* and the dotted line those of *forced* respiration.

Fig. 34.—Showing Pectoral and Abdominal Respiration.

The Pleura. — The interior of the *thorax* is lined by *serous* membranes (see "Serous Membranes") known as the *pleuræ.* Each *pleura* consists of a *closed* sac, a good idea of the arrangement of which is given by a woven night-cap, closed at both ends, or by a long silken purse. One portion of this sac is permanently attached by its *outside* to the *inside* wall of the *thorax;* the remaining portion is *tucked in,* re-

flected, so as to form an internal sac, by which the lung is *invested.* In breathing, therefore, the two *inside* surfaces of the pleura, which are moistened by its peculiar secretion, are *free*, and *rub* against each other.

The Structure of the Lungs.—The lungs (see Figs. 6, 30, and 35) occupy the greater part of the



A. Larynx.
B. Trachea, showing cartilaginous rings.
C. Bronchial tubes, the soft parts of the right lung being dissected away to show air-tubes.
D. Left lung.
E. *Ultimate* bronchial tubes.

Fig. 35.—Trachea and Lungs.

cavity of the chest. They consist of two large conical, spongy, elastic organs, which contain millions of little cavities or *air-cells*, the scheme of their structure being the mutual exposure of the largest *surfaces* of *air* and *blood* to each other.

The *right* lung comprises *three*, the *left two* lobes. Each lung consists of an immense multiplication of minute air-*sacs*, connected with a very

complex system of air-*tubes*. It also contains a very elaborate system of *capillaries*, by which the blood is distributed over the *surface* of the air-cells, together with other larger bloodvessels for conveying the blood *to* and *from* the lungs.

All these various parts are held together by means of *areolar* tissue. The lungs are supplied with lymphatics and branches from the *pneumogastric* nerve.

The Larynx, or voice-box, at the top of the *trachea*, is fully described in the section on the "Organs of the Voice."

The Trachea (from Gr., *trachus*, rough), or windpipe, is the principal air-tube of the lungs. It divides at its lower end into two smaller air-tubes, termed *bronchi*, one of which passes to each lung; its upper end terminates in the *larynx*, which is situated near the base of the tongue, at the back of the mouth. (See Figs. 6 and 35.) It is about 4 inches long and three quarters of an inch in diameter, and presents a rough, uneven surface, from which it derives its name, and which may be felt by rubbing the finger against the front of the throat. It consists of an external tube formed of fibrous membrane, supported and strengthened on its front and sides by 16 to 20 imperfect *cartilaginous* (gristly) rings (the hinder third being wanting). The absence of the cartilage from the posterior parts of the rings permits of the *flexibility* necessary for the free passage of the food during the act of *deglutition*.

But for these cartilaginous rings a very slight pressure, even bending the neck, would close the windpipe and produce suffocation. The back of these rings is completed by a white, fibrous, tough, inelastic membrane, termed the *perichondrium*, which also invests the surface of the rings.

The *inside* of the *trachea* is lined with mucous mem-

brane, covered with *ciliated epithelium.* Probably these *cilia* move in the direction of the *glottis.* The motion of these *cilia*, as observed under the microscope, somewhat resembles the waving of a corn-field in a steady breeze. One function of the *cilia* is the removal and *extrusion* of the dust and other mechanical impurities sucked in with the air during respiration, which would otherwise pass into and accumulate in the air-cells and produce inflammatory disease. The *cilia* receive the dust and pass it upwards till it reaches the back of the mouth. Their principal function is, however, the removal upwards of the *mucus*, which is always forming on the surface of the air-tubes, and which would otherwise gravitate into the air-cells.

Between the external fibrous and the internal mucous membrane of the trachea is a sheet of *transverse unstriped* muscular fibre. This muscle, termed the *trachealis muscle*, helps to complete the circle of the *cartilaginous* rings, and by its contraction alters the diameter of the tube.

Bronchi and Bronchial Tubes.—The *trachea* divides, at its lower extremity, into two *bronchi;* these again into other smaller tubes, termed *bronchial tubes.* These tubes are described as *secondary*, *tertiary*, and *terminal* bronchia. The *terminal* or *ultimate* bronchial tubes open into *lung-sacs*, or *infundibulæ*, or, as they are sometimes indefinitely termed, *lobules.*

The larger *bronchial* tubes have a similar structure to the *trachea;* the *cartilaginous* rings, however, differ from those of the *trachea* in being entire or complete rings. They are lined with *ciliated* epithelium.

The smaller *bronchial* tubes do not contain any cartilaginous rings, and are exceedingly delicate in their structure. They are about 1-70th of an inch in diameter. The function of the *trachea* and bronchial

tubes is to distribute air to the air-cells. Inflammation of the mucous membrane lining these tubes is termed *bronchitis*.

The Lung-Sacs and Air-Cells.—The *lung-sacs*, or *infundibulæ*, as they are sometimes termed, are small, irregular, funnel-shaped sacs or pouches. They are attached to the *terminal* bronchial tubes. Their

Terminal air-vesicles of the human lung, hanging to a branch of the bronchi as berries hang to their stalk.

Fig. 36.—Lung-Sacs and Air-Cells.

sides are everywhere *honeycombed* with minute cells—the *air-cells*, of which it is said there are as many as 18,000 in the walls of one lung-sac. It has been calculated that the human lungs contain 600 millions of these air-cells.

It has been estimated that the lungs expose a surface of 1,400 square feet to the atmosphere.

The lung-sacs and air-cells consist of an *outer* coat of *connective* tissue, and an inner *mucous* coat; they probably contain minute traces of organic muscular fibre. The mucous membrane of the air-cells is lined with *squamous* epithelium.

Nerves of Respiration.—The lungs and air-tubes are chiefly supplied by nerves derived from the *sympathetic* and *pneumogastric* nerve. The diaphragm receives the *phrenic* nerve, from which it derives its power of motion.

Quantity of Air Respired.—Ventilation.—

An adult breathes about eighteen times per minute, or about 9,000,000 times in each year. The total quantity of air contained in the lungs of an average man is about 250 cubic inches; the quantity changed or taken in by an ordinary inspiration is about 20 to 25 cubic inches. A man who, when naked, could take in 190 cubic inches by a *forced* inspiration, could, when dressed in his ordinary clothes, only inspire 130 cubic inches. About 375 cubic feet of air are respired daily, or about 130,000 cubic feet per annum. In every workshop or sleeping-room 800 cubic feet of space should be given each person, and the air in this space should be changed by ventilation at *least* twice each hour. Tight dress, sleeping with the head under the bedclothes, or in a cramped position, seriously lessen the growth and vigour of young people by impeding respiration.

Capillaries of the Lungs and Air-Cells.—The whole of the interior of the lung-sacs and air-cells is lined with a very minute, delicate, and exquisitely beautiful *network* of *capillary* bloodvessels. These vessels, notwithstanding their excessive minuteness, possess a distinct *wall* and internal *bore* large enough to permit of the passage of the *red corpuscles* of the blood.

Why the Air passes into the Lungs, and **not** into the **Cavity of the Thorax.**—Let A (Fig. 37) represent a glass cylinder, C a *tube* open at both ends fitted into the cylinder by an airtight fitting, B a *bladder* tied to the outside of the tube, and D a moveable airtight *piston* fitting into the lower part of the cylinder. When the piston D is *lowered*, a *partial vacuum* is produced; the air therefore rushes through the open tube into and *inflates* the bladder; when the piston is *raised*, the internal

capacity of the cylinder is reduced, the included air condensed, and the sides of the bladder driven in by its pressure, the contents of the bladder being expelled through the open tube, and the bladder itself entirely collapsing. If A be supposed to represent the *thorax*, B the *lungs*, C the *trachea*, and D the *diaphragm*, the action just described is very similar to what takes place in the process of breathing. This experiment may be made more interesting by substituting the *lungs* and *windpipe* of a sheep for the glass tube and bladder.

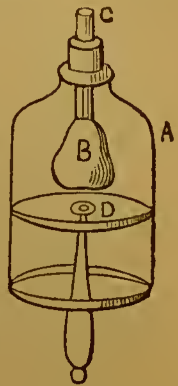


Fig. 37.

Wounds in the Thorax.—In the last experiment let an opening be made in the side of the cylinder A; on lowering the piston, air will also rush in through this aperture, as well as through the open tube. If the aperture in the cylinder be *less* than the mouth of the tube, the bladder will become *partially* inflated; if, however, the aperture in the cylinder be *larger* than the orifice of the tube, the air will rush in more quickly through the hole in the cylinder than through the aperture of the tube, and the bladder will remain *collapsed.*

This is just what takes place in *wounds* of the *thorax;* a large incision, as a stab from a bayonet, or a sword cut, by permitting the air to enter into the cavity of the chest, between the sides of the pleura, and press on the exterior of the lungs and drive out their contained air, would cause them to shrink up, and produce death by *suffocation.*

Suffocation may also be produced by internal bleeding, in which case the *lung-sacs* and *air-tubes* become filled with blood, to the exclusion of the air necessary for the purification of the blood.

Coughing consists of a series of short, violent, spasmodic, interrupted expirations through the mouth. These short interrupted expirations are produced by the sudden closing and bursting open of the glottis. Coughing is preceded by a long inspiration. It is a *reflex* action, usually excited by excess of *mucus* occasioned by discase, food that has passed the wrong way, cold air, or some other irritant acting on the *trachea* or *bronchial* tubes. It is termed a *reflex* action because the morsel of food or other irritant in the air-passages acts upon the *afferent* nerves, which convey the impression to the spinal cord; the spinal cord then transmits a *motor* impulse to the muscles of the chest and the diaphragm to expel the offending body, the *motor* effect being thus a *reflected* one.

Sneezing.—The process of sneezing is very similar to that of coughing, and differs from it only in the fact that the communication between the mouth and the windpipe is partially or entirely cut off by the *velum palati* (soft palate), (Fig. 6), so that the blast of air is driven more or less completely through the nose. Sneezing is also a *reflex* movement; its object is the expulsion of offending substances from the air-passages of the nose.

Sighing is a slow and *deep* inspiration, followed by an cqually slow and full expiration. It is generally supposed to result from mental depression, but it may be caused by almost any kind of strong mental affection, such as prolonged attention. In the latter case it arises from the nervous power, which should be distributed to the lungs to enable them duly to perform their *respiratory* functions, being monopolized by the brain; a series of vcry feeble inspirations therefore necessitates an occasional *compensatory*, very deep, full, and prolonged inspiration, which constitutes a sigh.

Asphyxia (from Gr., *a*, not, and *sphuzo*, I beat), or *apnœa* (from Gr., *a*, not, and *pneo*, I breathe), is the cessation of breathing. Unless purely temporary, it always results in death. It may be caused by spasm of the *glottis* or the muscles of respiration, by breathing poisonous or irritating gases, by the withholding of the nervous influence through apoplexy, paralysis, the section of the *pneumogastric* nerve, pressure on that nerve (as in dislocation of the neck), the brain's becoming charged with *venous* blood, obstruction of the mouth or the air-passages.

Drowning, strangulation, and suffocation, whether caused by choke-damp or the carbonic acid of a ship's hold, produce death by asphyxia. *Bronchitis* and inflammation of the *lungs* usually produce death by obstructing the air-passages with phlegm, mucus, or pus; these diseases are therefore doubly dangerous in very young children, who have neither the sense nor the power to relieve themselves by coughing.

Artificial Respiration. — Several methods of restoring *respiration* in cases of drowning have been devised; that of Dr. Sylvester appears to be the most efficient. It consists in holding the two arms by the elbows, and working them *up* and *down* like two *pump*-handles, the patient being placed on his back, his head inclined upwards, and his tongue kept down to leave the respiratory tract open. In this process about 44 cubic inches of air are alternately *inhaled* and *expelled* by the changes produced in the internal capacity of the chest. Care should be taken that the patient be kept warm.

ANIMAL HEAT.

Animal heat is chiefly *developed* by the *combustion* of the carbon, hydrogen, sulphur, and phosphorus of the food and tissues consequent on the process of *respiration;* but it is regulated by the action of the skin through the medium of the perspiration, which carries off the excess in the form of *latent heat*, so that a man may even bear the heat of a furnace with comparative impunity. (See "The Skin.")

The temperature of *arterial* blood is about 100° F.; that of *venous* blood about 98° F. When the body falls much below this temperature death supervenes. During starvation the temperature of the body falls; during *fever* it sometimes rises to 107° or even 110° F.

It has been estimated that the amount of heat generated in the body of a man in 24 hours would raise the temperature of 6 gallons of water (about 60 lbs.) from 32° to 212° F.

NUTRITION AND REPAIR.

Nutrition is the process by which the *plastic* elements of the *liquor sanguinis* are built up into the tissues. Nutrition is the *antagonist* of decay: in infancy and youth it *exceeds* decay and determines *growth;* in middle age it *balances* decay; but during old age *decay* exceeds *nutrition*, and gradually ruins and brings down the fabric, its complete and final victory culminating in death.

Each tissue in its *normal* state exercises a *selective power*, by which it appropriates and builds into its own structure the material or pabulum it requires: thus the hair, skin, muscle, nerve, bone, &c., each selects and assimilates from the same liquid—the *liquor sanguinis*—the principle essential to its development, growth, or repair.

The material out of which the tissues are immediately formed has been termed *sarcode*, *protoplasma*, *blastema*, *formative material*, and more recently, by Dr. Beale, *germinal matter*. Dr. Beale, whose original histological investigations and discoveries are most important, states that all living structures are made up of *germinal matter*, or *formative material*, and *formed* material; and that the power to select from the *liquor sanguinis* the material necessary for the nutriment of the tissues resides in the *germinal matter* exclusively.

As previously described, the *liquor sanguinis* is supplied to the tissues by *osmosis* through the walls of the *capillaries*. *Nutrition* is active in proportion

to the *vitality* of the part. The greater the *vitality* of an organ or tissue, the more rapid and energetic is the metamorphosis, change, or decay of its component particles; and therefore during life the more vigorous and energetic must be the *nutrition* of that part. Those tissues, therefore, as the skin, muscle, mucous membrane, and nerve, which are the seat of the most rapid and constant metamorphoses of births and deaths of new particles, are most *abundantly* supplied with *capillaries;* and in general it may be said that the number and activity of the capillaries of any tissue is in direct proportion to its vitality. Bone, cartilage, ligament, and tendon, which are subject to comparatively little interchange and activity, contain relatively but few *capillaries.*

When the supply of blood is cut off from a part by a ligature, pressure, or any other means, the part mortifies, or dies and sloughs away. Deer cast their antlers, birds *moult* or cast their feathers (see "Death"), and the milk-teeth of infancy decay from this cause.

Cacoplastic and Aplastic Lymph (from Gr., *a*, not; *plasso*, I form; and *kakos*, bad).—In certain diseases, as consumption and scrofula, the blood is partially deficient in *constructive* power, and unable to build up perfect tissue; forms *tubercle*, an inferior form of organization, which may be regarded as a product of abortive *nutrition;* in this state the blood is said to be *cacoplastic.* In other cases the *liquor sanguinis*, or *lymph*, is entirely deficient in constructive power, as in *pus;* it is then said to be *aplastic.*

Conditions of Healthy Nutrition.—Dr. J. H. Bennett gives the following as the conditions of *healthy* nutrition :—

(1.) A healthy *quality* of the blood.
(2.) A proper *quantity* of blood in the part.

(3.) A certain influence of the *nervous system.* In some cases, where a nerve is injured or destroyed, the part not only wastes, but *ulcerates* away.

Feelings of hope and confidence are highly favourable to the cure of disease, while depression and foreboding of evil not only aggravate it, but frequently produce fatal results.

(4.) A *healthy state* of the part to be nourished.

Repair of Injuries.—All animals possess a greater or less power of repairing injuries or restoring lost members; the latter power is possessed to any considerable extent by the lower animals only. In the case of a sharp, incised, clean wound, if the opposite sides be brought close together, and into perfect *coaptation*, they will frequently heal with great rapidity by mere adhesion and without the intervention of any appreciable quantity of *lymph* or *blood;* this, which is the most satisfactory to the surgeon, is described as *immediate union.*

When the parts are not brought properly together, or slight inflammation sets in, a portion of the *liquor sanguinis*, known to the surgeon as *plastic* or *coagulable lymph*, oozes from the adjacent bloodvessels, becomes organized, and joins the surfaces together by *adhesion;* this is known as *healing by the first intention*, or by "adhesive inflammation."

When there has been considerable loss of substance, the *coagulable lymph*, or *liquid blastema*, which is poured into the wound, becomes gradually organized, and in *subcutaneous* wounds, or when the air is excluded, develops into a *fibrous* tissue, which fills up the cavity and connects the adjacent parts. This is afterwards very apt to waste away, contracting and leaving a cicatrix or scar. If, however, the air be not excluded, the *coagulable lymph* forms into cells, those on the surface, exposed to the air, degenerating into *pus*, the yellowish creamy liquid which escapes from sores.

When the injury is severe, and its surface very extensive, the formation of this *pus* forms a serious and sometimes fatal drain on the constitution. Healing by this method is termed healing by *granulation*. The formation of new bloodvessels in these tissues probably is produced by the escape of blood corpuscles at particular points in files or rows, so as to form passages in the soft material of which it is composed, the corpuscles being absorbed, and the channel ultimately acquiring proper walls, which become continuous with the capillaries from which they originated. It is of the utmost importance, in the case of extensive surface *burns*, particularly of children, to preserve the wound from the atmosphere if we would prevent fatal results. Bone, skin, white nerve fibre, the fibrous tissues, serous and mucous membranes, the capillaries, and the blood, may be perfectly restored; but the glandular and muscular tissues and grey nerve substance are not reproduced.

Repair of a Broken Bone.—When a bone is fractured, more or less blood from the ruptured vessels of the bone and its *periosteum* effuses into the wound and forms a *coagulum*. Shortly afterwards, a semi-transparent organizable fluid (the *plastic lymph*) exudes into the coagulum and solidifies, joining the ends of the bone together; also, if the bone is tubular, forming a *plug*, filling the portion of the medullary canal immediately adjacent to the fracture, and likewise forming an external ring, encasing the exterior of the fracture. Earthy matter is deposited in this substance until it forms a hard, spongy, bony mass, termed by Dupuytren the *provisional callus*. This is afterwards gradually removed by the *absorbents*, Haversian canals being developed, and true bony tissue, forming the *permanent callus*, being deposited.

According to Mr. Paget, the *provisional callus* described by Dupuytren is not formed in the bone of a human being when it is kept at rest during the period of its recovery. When the ends of the bone are not properly adjusted, they are united by the formation of a ligamentous or cartilaginous substance.

SECRETION AND EXCRETION.

STRUCTURE OF GLANDS.

All animals except the lowest classes are endowed with special organs, as the salivary glands, and the liver, whose duty it is to separate, elaborate, or *secrete* from the blood certain fluids or substances *useful* to the body. They are also endowed with other organs, whose duty it is to separate or *excrete* from the blood certain *useless* or *injurious* substances. The former are termed organs of *secretion;* the latter of *excretion.*

Excretion and Secretion. (See page 13.)

Organs of Secretion.—The principal *glands*, or organs of *secretion*, are the salivary glands, the liver, pancreas, and the lachrymal and mammary glands. The lesser glands are the synovial glands of the joints, ceruminous glands of the ear, sebaceous and sudoriparous glands of the skin, Meibomian glands of the eyelids; the glands of Brunner, Peyer, and Lieberkühn; and the gastric and intestinal tubuli of the alimentary canal.

Plan of Structure.—All glands are formed on the same principle. They consist mainly of a *secreting membrane* and a network of *capillaries.*

The *secreting* membrane consists of *basement* membrane covered by a layer of *epithelial* cells. The basement membrane is *homogeneous* and *structureless.* The *epithelial layer* varies in thickness, and, to a certain

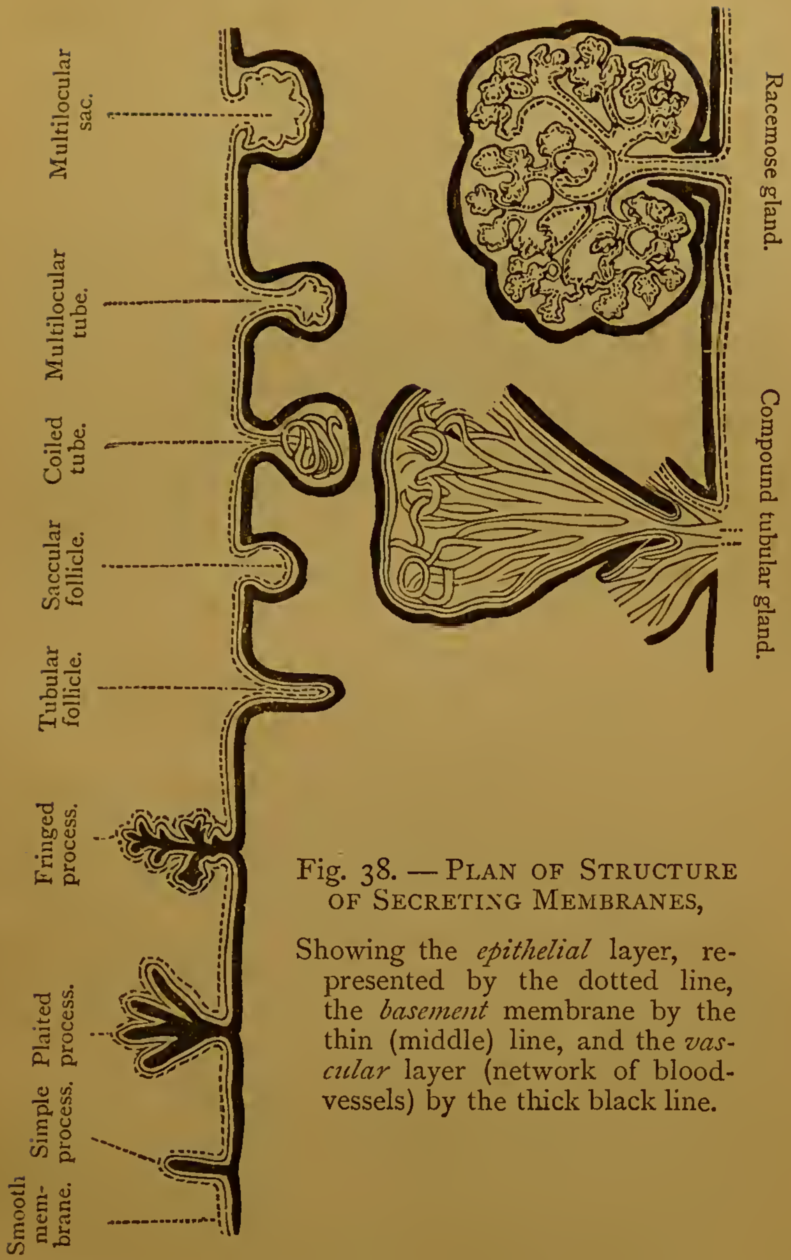


Fig. 38. — Plan of Structure of Secreting Membranes,

Showing the *epithelial* layer, represented by the dotted line, the *basement* membrane by the thin (middle) line, and the *vascular* layer (network of blood-vessels) by the thick black line.

extent, in the size and form of the cells of which it is composed.

The *process* of secretion is supposed to be effected through the *agency* of these *cells.*

The scheme of the structure of a gland is to bring a greater or less extent of *secreting* surface within a small compass. This is effected by the folding up or reduplication of the secreting membrane into *recessions* of various forms—*tubular*, *saccular*, &c. These folds or recessions are surrounded with a *network* of *capillaries*, and the whole bound together by *areolar* tissue. Glands are supplied with *nerves*, violent mental emotions and anxiety in some cases completely altering the nature of the *secretions.* They are described as *simple* and *compound.* All true glands possess *excretory ducts* for the removal of their secretion. The general structure and variety of glands is illustrated in diagram Fig. 38.

Simple Glands may be described under five varieties, according to the shapes of the *recessions* by which they are formed :—

1. *Tubular crypts*, or follicles, as the gastric or intestinal tubuli (Fig. 15, f).
2. Saccular follicles, as the *Meibomian* glands of the eyelids.
3. Long coilcd tubes, as the *sudoriparous* glands (Figs. 49 and 52).
4. Multilocular tubes, as the more complex *gastric tubuli.*
5. Multilocular sacs, as the *follicles* of the *tonsils* or the *gastric* glands of the ostrich.

Compound Glands may be described under three varieties :—

1. Compound *tubular* glands, consisting of a number of branched tubes ending free or in loops, like those of the kidney (Fig. 47).
2. Compound *vesicular* glands, or *racemose vesicular* glands, which consist of branched tubes, the extremities of which terminate in clusters of short *saccules* or *vesicles*, as those of the salivary glands (Fig. 44) or the pancreas.

3. *Reticulated* glands, consisting of *tubuli* which have not free or looped ends, like those of the kidneys, and which do not terminate in minute sacs, like those of the *racemose* glands, but form a close delicate network like those of the liver.

Vital Selective Force.—The nature of the *secretion* elaborated by any particular gland depends not upon the *structure*, but upon the special *selective* power of its *epithelial* cells. From the want of a better term this power has been described as *vital selective force.*

THE LIVER, GALL-BLADDER, AND THE BILE.

Appearance, Size, and Function.—The liver is a large reddish-brown organ. It is the largest gland in the body, is about 13 inches long and 7 inches broad, measures about 90 cubic inches, and weighs 3 to 5 lbs. It secretes 3 to 5 lbs., or about its own weight, of a yellowish green liquid, termed *bile*, per day.

Situation.—The liver is situated in the upper part of the abdomen, immediately under the *right* half of *diaphragm*, into the *concavity* of which it is fitted, and to which it is attached. It overlies and rests on a portion of the pyloric pouch of the stomach, upper part of the colon, and the kidney. (See Fig. 8.)

Coats or Investments of the Liver.—The greater portion of the surface of the liver is covered by the *peritoneum.* It is also completely invested with a *fibrous* coat of its own. This coat, which is known as *Glisson's capsule*, enters and lines the *portal* canals.

Structure of the Liver.—The liver consists of five lobes, viz., two larger—a *right* and a *left* lobe, and three smaller—the *lobus quadratus*, *lobus Spigelli*, and the *lobus candatus.*

The compact reddish brown substance of which the

mass of the liver is composed consists of a *secreting* and a *vascular* structure. The secreting structure consists of an immense number of minute granules, or

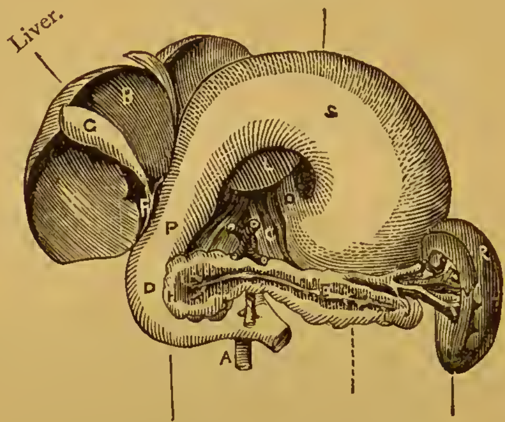


Fig. 39.—STOMACH, LIVER, AND PANCREAS.

The liver and stomach are turned up to display the duodenum, pancreas, spleen, and their ducts and vessels. The pancreatic duct traverses the whole length of the gland.

B. The under surface of the liver.
G. Gall-bladder.
F. Common bile-duct, formed by the union of the cystic duct leading from the gall-bladder and the hepatic duct from the liver.
O. The cardiac end of the stomach, proceeding from the œsophagus.
S. The under surface of the stomach.
P. Pyloric end of the stomach.
D. Duodenum.
H. Head of pancreas.
T. Tail ,, ,,
I. The body of the pancreas, the substance of which is removed in front so as to show the pancreatic duct, E, and its ramifications.
R. The spleen.
V. The *hilus* at which the bloodvessels enter.
C. The crura of the diaphragm.
A. The aorta.
L. Part of under surface of *left* lobe of liver.

nucleated polyhedral cells, of a brownish-yellow colour, held together by areolar tissue. (See Fig. 40.) These, termed *hepatic cells*, are 1-1,600th to 1-800th inch in

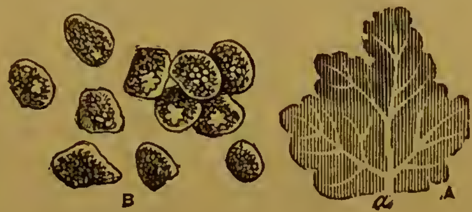


Fig. 40.—STRUCTURE OF HUMAN LIVER.

A *a*. Branches of *hepatic* vein (*intra*lobular). The shaded portion shows four *lobules* attached to the branches of the *hepatic* vein like leaves to the branches of a tree. This diagram represents the *lobules* twice their natural size.

B. *Hepatic* or biliary cells, the *nucleated* cells of which the *lobules* are composed, magnified 200 times.

diameter; they are clustered in lobules, termed *Malpighian lobules*, or *acini*, of irregular form, about the size of a pin's head. These *lobules* or *acini* are

Fig. 41.—HEPATIC VEIN AND LOBULES.

Vertical section of human liver, showing—

A. Hepatic (*intra*lobular) vein, trunk with tributary twigs.

B B B. Biliary *lobules* attached, like leaves to the terminal branches of a tree.

arranged upon the ultimate branches of the *hepatic veins* like leaves upon a tree, thus giving to a *vertical* section of the lobules the peculiar *arborescent* appearance shown in the diagram. (See Fig. 41.) The *hepatic* cells, which form its true *parenchyma*, compose the great mass of the liver, and entirely fill up the meshes and interstices of its *vascular* network, being moulded about the walls of the *capillaries* and the *hepatic ducts*.

The *lobules* are separated (see Figs. 41 and 42) from each other by the *plexuses* of the portal veins and *hepatic* ducts by which they are surrounded. It is uncertain whether they have distinct capsules.

Bloodvessels of Liver.—The liver is supplied with blood by the *portal* vein and *hepatic* artery. The larger branches of these vessels, together with the larger *hepatic ducts*, are contained within common sheaths of connective tissue termed *portal canals*.

Portal Canal.—The *portal canal* is the common sheath of areolar and elastic tissue which ramifies through the substance of the liver, affording a common passage for the ramifications of the *portal* vein, the *hepatic* artery, and the *hepatic* duct. It is lined by the membrane termed *Glisson's capsule*.

Portal Vein.—The portal vein, or the *vena porta*, is a large vein which enters the *porta* or gateway of the liver. It is formed by the junction of the veins from the stomach, intestines, pancreas, and spleen, viz., the gastric, the superior and inferior mesenteric, and the splenic veins. The impure *venous* blood is collected from the organs mentioned, and instead of being conveyed directly to the *vena cava*, like the rest of the venous blood, is passed through the liver, thus affording the material from which the *bile* is elaborated.

The more minute branches of the portal veins traverse the *interlobular* spaces, surround the *lobules*, and give off their ultimate ramifications, the portal capil-

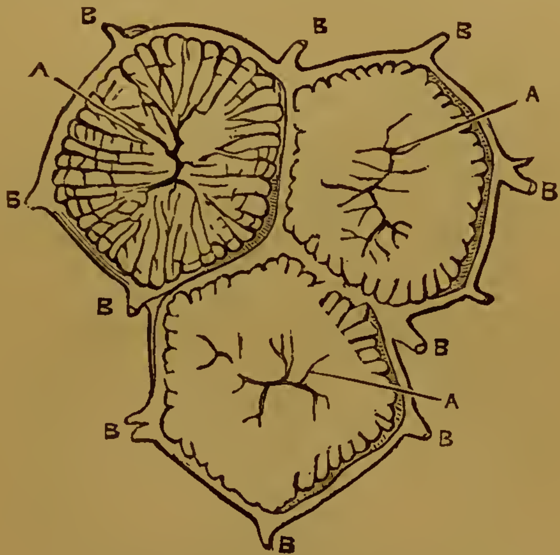


Fig. 42.—TRANSVERSE SECTION OF THREE LOBULES OF LIVER,

Showing the two principal systems of *bloodvessels* in the liver,

A A A. Hepatic veins, the *intra*lobular veins.
B B B. Network of portal veins, the *inter*lobular, which surround the lobules, giving off the *portal* capillaries which pass between the *biliary* cells to the centres of the lobules, where they join the rootlets of the *hepatic* veins.

laries, which pass into the interior of the lobules, and terminate in the commencing twigs (capillaries) of the *hepatic* veins. The *capillaries* of the *portal* vein thus hold the same relation to the *capillaries* of the *hepatic* vein that the general *arterial* capillaries hold to the *venous* capillaries.

Function of Portal Vein.—The *portal* vein supplies the impure blood from which the liver secretes

the *bile*. This has been proved by tying the *portal vein* just before its entrance into the liver, in which case no *bile* was secreted. No such result follows ligature of the *hepatic artery*.

The Hepatic Artery supplies the blood by which the liver is nourished.

Hepatic Ducts.—The hepatic or *biliary* ducts probably commence among the *hepatic* cells, pass off at the surface of the lobules, and join with others to form larger branches, which finally unite to form the

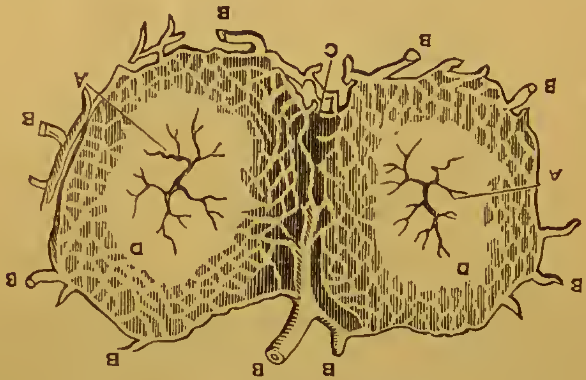


Fig. 43.—Transverse Section of Two Lobules of the Human Liver,

Showing *inter*lobular network of *biliary* or *hepatic* ducts surrounding lobules, and sending off branches between the *biliary* cells towards the centres of the lobules.

A A. Branches of hepatic (*intra*lobular) veins.
B B. Branches of hepatic ducts surrounding lobules.
C. *Inter*lobular spaces.
D. Substance of lobule.

hepatic duct. The actual mode in which the *biliary* ducts commence, or their exact relation to the *hepatic cells*, has not yet been satisfactorily determined. The *hepatic duct*, after leaving the liver, joins the *cystic* duct

at a very acute angle (see 12, Fig. 7) and forms the common bile-duct (*ductus communis choledochus*), (see Fig. 39), which is about three inches long. The common bile-duct enters the *duodenum* along with the *pancreatic duct* at a very acute angle, passing obliquely between its coats for a distance of three quarters of an inch. At their commencements the *hepatic* ducts do not exceed 1-5,000th to 1-4,000th of an inch in diameter; they are lined with *glandular epithelium;* in the larger ducts it becomes *tesselated.*

The Lobules of the Liver, which are small, somewhat conically-shaped, granular bodies, 1-20th to 1-10th of an inch in diameter, or about the size of a millet seed, consist of a number of *hepatic cells* held together by the capillaries, and possibly by *basement membrane.* The spaces between the lobules are termed *interlobular spaces* or canals, and the *portal* veins which surround the lobules, and occupy these spaces, are termed *interlobular veins.* (See Figs. 40 to 43.) The interior or *central* portion of each *lobule* is occupied by a *capillary plexus* of the *hepatic* vein. The *hepatic veins* are therefore termed *intralobular veins.* The hepatic veins, occupying the *centre* of the lobules, pass at right angles from the axis of the lobules into larger branches of the hepatic veins at the base of the lobules; these veins are therefore termed *sublobular veins.* Each lobule is also surrounded by a network of *arterial* capillaries and of bile-ducts. Each *lobule* may, in fact, be regarded as a perfect *microscopic liver*, the whole liver being but a multiplication of these minute masses. The *biliary* or hepatic cells consist of spheroidal nucleated cells, 1-1,000th to 1-2,000th of an inch in diameter; they contain granules, oil globules, and pigment.

Nerves of the Liver.—The liver is principally

supplied with nerves from the *sympathetic* system, but it also receives branches from the *pneumogastric nerve.*

The Gall-Bladder is a small pear-shaped sac, situated under the right lobe of the liver. (See Fig. 39.) It is connected with the *hepatic duct* by the *cystic duct*, which is about one inch and a half long, and about the diameter of a crowquill. The gall-bladder consists of an external coat of fibrous tissue, containing *non-striated* muscular fibre, and an internal *mucous* coat lined with *columnar epithelium.* Its interior surface presents a peculiar honeycombed appearance. The human gall-bladder is capable of holding from one to two ounces of fluid; its principal function is to divert and retain the bile from the intestine during the period when digestion is not proceeding. The secretion of the bile is *continuous*, and not *remittent*, like that of the other digestive juices, but it is secreted most rapidly a few hours after a meal.

The Bile is a transparent, greenish yellow, somewhat viscid *alkaline* liquid; it has a disagreeable odour, and a peculiar, most nauseous, and bitter taste. Its *alkaline* properties enable it to *neutralize* the *acidity* of the *chyme.* It froths when shaken, and has a *soapy* feel. Ox-gall is used for cleaning carpets, and also as a powerful purging medicine. Its principal constituents are two *fatty acids*, *taurocholic* and *glycocholic* acids, which are combined with *soda*, forming two *soaps*, biliary *pigment*, and a small quantity of *cholesterin* (a peculiar fat), which is probably held in solution by *taurocholic acid.* When the *cholesterin* is in excess it gives rise to the formation of *gall-stones*, which sometimes, by stopping the passage of the *hepatic duct*, prevent the bile's escaping from the *liver* into the *duodenum*, in which case it is *absorbed* directly from the

liver into the blood, producing the disease known as *jaundice.* The peculiar yellow appearance of the skin, from which the disease takes its name, is due to the deposition of the *colouring* matter of the bile in the substance of the skin. The *organic* constituents of the *bile* consist principally of *hydro-carbons.*

CHEMICAL COMPOSITION OF HUMAN BILE.

Water			86
Solids	Taurocholic and glycocholic acids in combination with soda	9·14	= 14
	Fat	·90	
	Cholesterin	·26	
	Mucus and colouring matter	3·00	
	Inorganic salts	·70	
			100

This table shows the analysis by Frerichs of *bile* obtained from the *gall-bladder* of a young man killed by injury, but its composition varies very considerably in the same individual at different periods.

The *colouring* matter of the bile consists of *biliverdin*, a *green* pigment, which predominates in the *herbivora*, and *cholepyrrhin*, or *biliphæin*, a *brown* pigment, which predominates in human bile. When the latter substance is treated with *nitric* acid, it rapidly undergoes a series of changes of colour, becoming—1, green; 2, blue; 3, violet; 4, red; and 5, changes slowly to a yellow. *Nitric acid* is therefore used as a test for *bile* stains.

The Functions of the Bile are not very thoroughly understood, but it is now generally admitted by physiologists that among others it performs the following offices:—(1) it assists in the formation of the *chyle;* (2) it separates the *excrementitious*

and useless parts from the nutritious parts of the *chyme;* (3) it probably aids the absorption of the fat, moistening the *villi* of the intestines, and thus rendering them more penetrable by the neutral fats (by *osmosis*); (4) it stimulates the *peristaltic* action of the intestines, its presence in excess producing diarrhœa.

The Functions of the Liver are but imperfectly known, some of them being still subjects of discussion among physiologists; the following are, however, among those best determined:—(1) it aids digestion by the secretion of the *bile;* (2) it purifies the blood, removing injurious substances from it, the bile being principally an *excrementitious* substance possessing well-marked poisonous properties, and producing death by coma or insensibility when a sufficient quantity of it finds its way into the brain; (3) it elaborates two heat-giving substances, viz., *fat* and a *glycogenic* (sugar-forming) substance, which is burnt off in the pulmonary circulation as a *respiratory fuel;* (4) it promotes, through the stimulus of the bile, the healthy *peristaltic* action of the intestines; (5) Dr. Carpenter and other modern physiologists are also of opinion that it exercises an *assimilative* or elaborative action on the freshly absorbed *albuminous*, *saccharine*, and other elements of the food.

In the higher animals the action and development of the liver seems to be in the inverse ratio of those of the lungs; that when the lungs are largely developed the liver is relatively less developed; and that when the lungs are *less active*, as in warm climates, the liver is most energetic and most liable to disease. This would seem to show that the liver is not simply a *secreting*, but also a *depurative* organ, which, under some circumstances, *partially* relieves the lungs of their office by excreting a portion of the *waste* carbon.

When the *bile* accumulates in the system, as in certain cases of diseased liver, produced by *drunkenness*, the patient becomes at first rambling and delirious, and ultimately dies *comatose* (in a state of profound insensibility), through the brain's becoming poisoned by the action of the *bile.*

If the bile be allowed to escape from the system without mixing with the food in the intestine, the animal soon dies from emaciation and debility, thus proving its importance as an aid to digestion. Schwann tried numerous experiments on dogs, tying the bile-duct, and causing the bile to be discharged *externally* through an *artificial* opening. In sixteen out of eighteen cases the dogs died within two or three weeks. It is said, however, that if the dogs be allowed to lick the bile as it escapes from the wound, they will not die. Later experiments seem to show that if the *loss* of *bile* be compensated by a large increase in the quantity of food taken, the animal will live an indefinite time.

If a ligature be tied round the *portal* vein immediately before it enters the liver, no *bile* will be *secreted;* but a similar ligature tied round the *hepatic artery* produces no such effect, thus showing that the *bile* is mainly *secreted* from the *venous* blood supplied to the *liver* by the *portal* vein.

Glycogenic Function of the Liver.—Healthy blood drawn from the *portal* vein and the hepatic artery, and which has therefore not passed through the liver, yields no trace of *glycogenic* substance after the most careful examination, while it is easily detected in blood drawn, after traversing the liver, from the *hepatic* vein, thus proving it to be formed during the passage of the blood through the liver. If the branches of the *pneumogastric* nerve which pass

to the liver are severed, the *glycogenic* substance is not formed. This substance, together with the fat, is conveyed to the lungs and burnt off, thus helping to maintain the *animal heat.*

In certain *morbid* cases the respiratory organs are unable to perform their functions efficiently, and this *saccharine* substance is passed out of the system in the *urine:* this disease, which is usually fatal, is termed *diabetes mellitus.* The presence of the sugar in the urine is not the *cause*, but a *symptom* only of this disease.

SALIVARY GLANDS.

For a general description of the salivary glands and *saliva* see page 46.

The Salivary Glands are described as *conglomerate*, *racemose*, *vesicular* glands (from L., *racemus*, a bunch of grapes): they consist of numerous lobes;

Fig. 44. — Portion of Salivary Gland injected with Mercury,

Showing—1. Bunches of grape-like *vesicles.*
2. Salivary *ducts*, forming branching tubes.

these are made up of *lobules*, the whole being connected together by *ducts*, *bloodvessels*, and *areolar*

tissue. Each lobule consists of a collection of closed sacs, vesicles (see Fig. 44), or *acini* (about 1-1,200th inch in diameter), which open into a primary branch or rootlet of an *excretory* duct; these ducts unite to form the larger ducts by which the *saliva* is poured into the mouth. The walls of the lobules consist ot fine *basement* membrane, covered externally by a dense plexus or network of capillaries, and internally by a layer of *epithelium*. The lobes and lobules are invested more or less completely in a capsule of *areolar tissue*. The **nerves** of the salivary glands are derived from the *gustatory* or 5th cranial nerve.

PANCREAS AND PANCREATIC JUICE.

Appearance, Size, and Situation of the Pancreas.—The pancreas (from Gr., *pan*, all, and *kreas*, flesh), or sweetbread, is a soft, milky, or pinkish white tongue or *hammer*-shaped *gland*, about 7 inches long, 3 inches broad, and 1 to 2 inches thick; it contains about 5 cubic inches, and weighs from 3 to 5 oz. It probably *secretes* about half a pint per day of a fluid termed the *pancreatic juice*, which closely resembles the *saliva*.

It is situated in the *abdomen*, at the back of the stomach, immediately in front of the *aorta* and *vena cava*. Its *head* or larger end is placed in the concavity of the *duodenum* (see Fig. 39); its *tail*, or lesser extremity, which tapers off considerably, is in contact with the *spleen*. It is retained in its place by *areolar* tissue, and by folds of the *peritoneum*.

The Structure of the Pancreas.—The pancreas has no distinct capsule, but it is invested with an irregular covering of condensed *areolar* tissue. *Septa*, or partitions from the external covering, dip into the

substance of the gland, and divide it into *lobes* and *lobules*.

The *minute* structure of the pancreas closely resembles that of the *salivary* glands (see Fig. 44), consisting of *lobules*, each of which forms a distinct *racemose* gland. These *lobules* are invested by delicate coats of *areolar* tissue derived from the covering membrane. A number of these *lobules*, packed together in a denser investment of *areolar* tissue, constitutes a *lobe*. Each lobule consists of a number of dilated *vesicles* clustered round a system of *branching tubes*, and in its general arrangement has much the appearance of a bunch of grapes. These *vesicles* are therefore termed *acini* (from L., *acinus*, a grape-stone), and the glands themselves are termed *racemose* glands. These *acini*, or vesicles, lie in the meshes of a *network* of capillaries. The *acini*, and the branching tubes or *ducts* connected with them, are lined with glandular *epithelium* cells about 1-1,500th of an inch in diameter.

Pancreatic Duct.—The main *pancreatic duct* (see Fig. 39) commences at the left or smaller end (the tail) of the pancreas, traverses the gland from left to right, receiving numerous tributaries on its way, and leaves the *head* of the pancreas, entering the duodenum with the *common bile-duct* (see Fig. 7). The tributary or smaller ducts enter it at right angles, presenting much the appearance of the legs of a centipede. At its termination it is about the size of a crowquill.

The *pancreatic duct* consists of—1, an external wall of *fibrous tissue* containing elongated nuclei; 2, an interior lining of *mucous* membrane lined with *columnar epithelium*. The pancreatic duct frequently opens into the *duodenum* by a separate orifice *below*, but never *above* that of the bile-duct.

The Pancreatic Juice is a clear, colourless, structureless, viscid liquid, very much resembling *saliva* in appearance and general properties. Its specific gravity is about 1·010; it contains about 10 per cent. solid matter.

It is *alkaline*, but does not contain *sulphocyanide of potassium*, in which respect it differs from the *saliva*. It acts even more

powerfully upon *starch* (converting it into sugar) than *saliva.* It putrifies rapidly, by which fact it is distinguished from *pepsin* and *ptyalin.* It converts *fat* into a complete *emulsion*, and thus, by effecting its minute subdivision, promotes its absorption by the *villi* of the intestines in the formation of *chyle.* It is said, when the pancreatic duct is obstructed by disease, or diverted from the intestine, that the fat passes off unchanged in the stools. It is coagulated by heat, alcohol, nitric acid, and some salts. It is said to contain a peculiar animal principle termed *pancreatin*, or *phymatin.* Whether, and if so how, it acts on the *albuminous* portions of the food, is still a subject of discussion among physiologists.

Function of the Pancreas.—The pancreas has been called the *abdominal salivary gland;* it aids digestion—1, by *secreting* a juice whose special power is to digest *fatty* matters; 2, it also aids digestion of those *starchy* substances which have not been sufficiently acted upon by the *saliva*, by converting them into *sugar*, and thus rendering them *soluble* and capable of absorption; it likewise promotes *osmosis* by its liquidity.

DUCTLESS GLANDS.

The Spleen, Suprarenal Capsules, Thyroid Gland, and Thymus Gland.

The mammalia possess certain organs which resemble *glands* in their *external* form, but entirely differ from them in their *internal* structure and arrangement, more particularly in the absence of *ducts*, which are common to all *true* glands. These organs, however, being more allied in *external* appearance to *glands* than to other bodies, are usually classed among them, but are distinguished from the *true* glands by the term *ductless* glands. They are sometimes termed *vascular* or *blood* glands, because they are supposed, in some manner, to affect the composition or organization of the blood.

The Spleen.

Appearance, Size, and Situation of the Spleen.—The spleen (the *milt* of the lower animals) is a soft, exceedingly

distensible, oval, somewhat *crescent*-shaped body, of a dark purplish colour. Its interior or *concave* surface is broken by a *hilus* or fissure, through which the nerves and vessels pass to and from the spleen. It varies very much in size at different periods of the digestive process. When moderately distended it is about 5 inches long, 3 to 4 inches broad, and 1 to 1½ inches thick; it weighs about 7 ounces. Tying the *porta* is said to increase its size about 10 times. (See R, Fig. 39.)

Fig. 45.—Portion of Spleen,

Showing—1. *Splenic corpuscle*, or Malpighian body (the oval body in the centre of the figure).
2. Minute arteries.
3. The *trabecular* network (represented by the finer lines).

It is situated on the left side of the abdomen, the left hypochondriac region (see page 95), near the tail of the pancreas, immediately behind the larger (*cardiac*) end of the stomach, to which its *concave* surface is attached. Its upper convex surface is fitted to the *diaphragm*, which separates it from the 9th, 10th, and 11th ribs; its lower end lies over the left kidney. It is retained in its position by two folds of the *peritoneum*, being connected with the stomach by vessels and nerves; it is almost

entirely, but *loosely*, covered by a *serous* reflection from the *peritoneum* (the gastro-splenic omentum), which admits of great *mobility*.

Structure of the Spleen.—The spleen consists of—1, the *capsule;* 2, a network of *trabeculæ* or bars; 3, the *splenic pulp;* 4, the *splenic* or *Malpighian corpuscles* (see Fig. 45); 5, bloodvessels, nerves, and lymphatics.

The Capsule of the Spleen is an exceedingly *distensible* membrane, forming its outer and proper coat. It is composed of white and yellow fibrous tissue. Muscular fibre has been found in the capsule of the dog, pig, and some other of the lower animals.

The Splenic Trabeculæ (from L., *trabs*, a bar or beam).—The *trabeculæ* of the spleen form a network of bars (see Fig. 45) which traverses the whole of the interior of the organ. They are derived from the *capsule*, which also sends in *sheaths* that surround the bloodvessels, and consist of white and yellow fibrous tissue. They may be distinctly felt by introducing the fingers into the interior of the organ, and their general character and structure may be easily observed by washing a section of the *spleen* under a stream of water from the tap, the dark reddish *interstitial* matter, the *splenic pulp*, being washed away, and the white fibrous network forming the interior framework of the organ, and consisting of the larger trabeculæ, remaining. The more minute *trabeculæ*, which are composed of nucleated spindle-shaped cells, are not visible without the aid of the microscope.

The Splenic Pulp is the soft, friable, dark reddish substance which chiefly occupies the interstices of the *trabeculæ;* it comprises a *colourless* and a *dark red* substance. The *colourless* portion consists of caudate nucleated cells, little granular bodies, free nuclei, and minute nucleated vesicles about 1-1,000th of an inch in diameter.

The *red* portion consists of blood corpuscles, whole and disintegrated, crystals of *hæmatin*, and larger cells containing blood corpuscles in various stages of development or disintegration. The *splenic pulp* constitutes the true *parenchyma* of the spleen.

Malpighian Corpuscles.—The splenic or *Malpighian corpuscles* are little semi-opaque, somewhat gelatinous, oval bodies, about 1-40th of an inch in diameter. (See Fig. 45.) They are situated upon the ends of the arterial twigs, each of which, after *bifurcation*, sends out a network of capillaries which embraces or surrounds the Malpighian corpuscle. It is probable that the substance of the corpuscle is traversed by the smaller capillaries,

but it is doubtful whether the corpuscles have any distinct capsules.

The Bloodvessels, Nerves, and Lymphatics of the Spleen.—The *splenic* artery is the *largest* branch of the *cœliac* axis; its branches are encased in white fibrous *sheaths* derived from the *splenic capsule.* The spleen is most abundantly supplied with *blood*, the supply apparently far exceeding that required for its *nutrition.*

The *splenic vein* forms the largest branch of the *vena porta:* it has no valves. Its branches also, like those of the artery, receive a fibrous investment from the *capsule;* these *sheaths* are connected throughout with the *trabeculæ.*

The Nerves of the spleen are derived from the *splenic plexus*, and from the right *pneumogastric* nerve; they are principally distributed to the coats of the arteries. It is abundantly supplied with lymphatics, the arrangement of which is not understood.

Functions of the Spleen.—Though the structure of the spleen is very peculiar, differing from that of all the other organs in the body, and has been well studied by Gray, Huxley, and other eminent physiologists, yet its *function* may be said to be quite undetermined. It probably acts—1, as a *receptacle* for and a *regulator* of the *quantity* of blood used in digestion, relieving the overcharged bloodvessels of the stomach, liver, and other adjacent organs; 2, it probably exercises some influence on the *cell* formations of the blood, the red corpuscles being said to be more numerous after the blood has passed through this organ. It is said that animals from whom it has been extirpated do not seem to suffer any *permanent* injury. This most probably arises from its function being taken up by other organs. The ancients described the spleen as the seat of melancholy, vexation, and ill-humour; hence the origin of the term *splenetic.*

The Suprarenal Capsules are two yellowish, triangular, cocked-hat-shaped bodies, situated just over the kidneys, to which they are loosely attached by areolar tissue. (See 1, Fig. 47.)

The Thyroid Body is situated at the upper part of the

trachea on each side of the base of the larynx, and is one of the *simplest* of the *vascular* glands. (See Fig. 6.) It is of a brownish red colour, and comprises two lateral lobes, connected by a narrow portion, termed the *isthmus*, which extends across the front of the third or fourth ring of the *trachea*. Its weight varies from one to two ounces ; it is soft and very vascular, and consists of masses of closed *vesicles* connected together by a *stroma* (fibrous matrix) of connective tissue, which are aggregated into lobules. The thyroid gland has no excretory ducts, and its *function* is quite unknown. It is the seat of the hideous disease known as *goitre*, *Derbyshire neck*, and *bronchocele*, so common in Switzerland.

The Thymus Gland is a pinkish grey organ, which is situated at the base of the neck and upper part of the *thorax*. It lies behind the *sternum* (breast-bone), and rests on the *aortic arch*. Its *function* is unknown.

THE KIDNEYS AND THEIR EXCRETION.

Excretion.—(See page 13.)

Appearance, Situation, and Size of the Kidneys.—The kidneys are two dark, reddish brown,

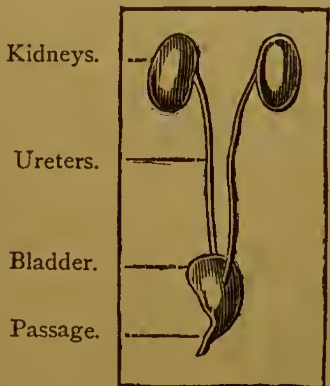


Fig. 46.—Plan of Urinary Organs.

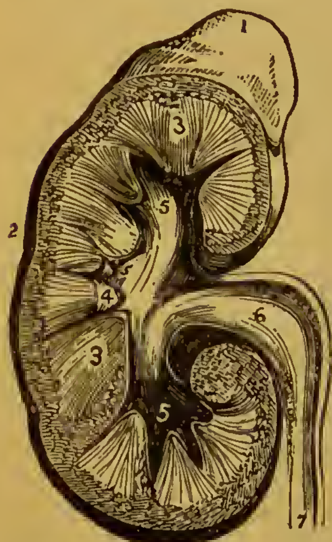
bent, oval-shaped bodies, situated in the loins, at the back of the cavity of the abdomen, one on each side of the lowest *dorsal* and upper *lumbar* vertebræ. They

lie *outside* and behind the *peritoneum*, the *left* kidney lying behind the larger end of the stomach. They are surrounded by much loose *areolar* tissue and *fat*, which give them much additional support and protection, and help to keep up their temperature; they are retained in their respective positions chiefly by the bloodvessels, nerves, and ureters.

The internal or *concave* border of the kidney is penetrated by a notch or fissure, termed the *hilus*. This opening affords *entrance* to the renal artery and the *nerves*, and *exit* to the ureter, renal vein, and absorbents.

The kidneys weigh about 5 ounces each, and are about 5 inches long, 2 inches wide, and 1 inch thick.

Structure of the Kidneys.—Each kidney is enclosed within its own proper fibrous coat or *capsule*, which is composed of *fibro-areolar* tissue. This invest-



1. Suprarenal capsule.
2. Cortical or vascular portion of kidney.
3, 3. Medullary portion (*tubuli uriniferi*, forming Malpighian pyramids).
4, 4. *Papillæ* formed by apices of pyramids.
5, 5, 5. Three *infundibulæ*, or funnel-shaped branches of the *sinus* of kidney.
6. Pelvis.
7. Ureter.

Fig. 47.—Section of Kidney and Suprarenal Capsule.

ment passes in at the *hilus* and lines the *sinus* and *infundibulæ*, also affording sheaths to the nerves and bloodvessels, and, according to some physiologists, forming the *matrix* of the kidney.

If a very thin longitudinal slice of the kidney be placed between two pieces of glass, and examined by a microscope of moderate power, *two* distinct structures, constituting the *parenchyma* of the kidney, may be observed, viz. :—

1. The **cortical** (outer) layer, about one-sixth of an inch in thickness, which consists of a soft, granular, and *vascular* substance, studded with dark *red* spots, the *Malpighian corpuscles.* This substance also dips into the interior or *medullary* portion of the kidney.

2. The **medullary** or interior portion, distinguished by its *striated* appearance.

The Cortical structure forms about three-fourths of the substance of the kidney, and consists chiefly of *convoluted* tubuli uriniferi, *Malpighian corpuscles* (see Fig. 48), bloodvessels, nerves, and lymphatics, held together by *areolar* tissue and *granular* substance.

The Medullary or Inner Structure of the Kidney is paler and firmer than the *cortical* portion, and is *striated* even to the naked eye. It consists chiefly of straight *tubuli uriniferi.* These *tubuli* are collected into conical masses termed *Malpighian pyramids.* There are eight to fifteen pyramids (see Fig. 47) in each kidney. The *bases* of the pyramids are turned to the *surface* of the gland, their *apices* being consequently turned towards the *centre* of the organ. The *apices* of two or three cones or pyramids combine to form a *papilla*, which projects into the *sinus* of the kidney. Each *papilla* is surrounded by a small pouch or *cap* of mucous membrane termed the *calyx.* The funnel-shaped spaces between the papillæ are termed the *infundibulæ ;* the infundibulæ open into the *sinus.* The *sinus* is an irregular cavity in the middle of the kidney, adjoining the *hilus ;* it opens into the pelvis or expansion of the *ureter*, which communicates with the bladder. The *uriniferous tubuli* open into the *calyces* at their base, which transmit the urine to the sinus ; thence it is conveyed by the *ureter* to its temporary receptacle, the *bladder.*

The Tubuli Uriniferi are minute microscopic tubes, consisting of simple *basement* membrane, lined on the interior with thick *glandular epithelium.* The *straight tubuli* of which the *cones* of the kidney are composed are largest at the apex of the cone. They become smaller by repeated *bifurcation* (dividing into twos) as they proceed towards the surface, where they become *tortuous* or *convoluted*, and enter into the formation of the *cortical* substance. The *convoluted* portion of the *tubuli* and their terminations abound in little flask-like *dilatations* which contain the *Malpighian bodies.* (See Fig. 48.)

The Malpighian Bodies, or the **Glomeruli** of the kidneys, are little rounded bodies about 1-120th of an inch in diameter. They consist of minute *arterial tufts* encased in delicate trans-

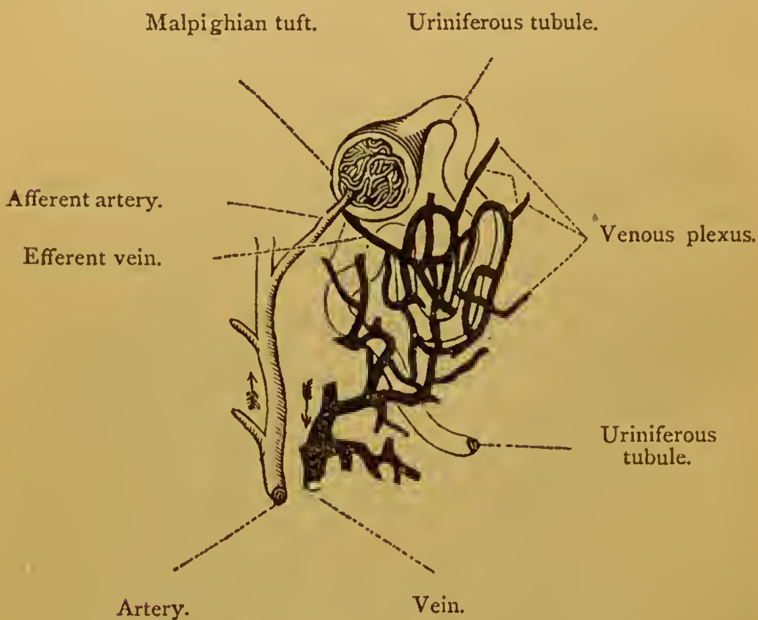


Fig. 48.—Plan of Circulation in Kidney.

parent *capsules.* A little *artery*, termed the *afferent* vessel, or *vas inferens*, passes through the wall of the *saccule* or dilatation in the uriniferous tubule; it then splits up into four or five smaller arteries, which form little arterial tufts (*the Malpighian corpuscles*); the *ultimate* branches of the *artery* unite to form the vein termed the *efferent* vessel, or *vas efferens*, which *emerges*

from the corpuscle in close proximity to the *afferent* artery. The *efferent veins* form the capillary *venous plexuses* which surround the *straight* tubuli uriniferi, and supply the blood from which the *urea* and *solid* portions of the urine are excreted. The *liquid* or aqueous portion of the urine is supposed to *exude* through the walls of the arteries of the *Malpighian corpuscle*, thus, as it were, flushing and dissolving away the more solid contents of the *uriniferous tubuli*, and preventing their obstruction.

The Renal Arteries (see Fig. 26) enter the kidneys at the *hilum*, after dividing into four or five branches along with the *renal veins* and *ureters*. They are exceedingly large for the size of the organs they supply. It has been estimated, from the size of the arteries in relation to those of other parts of the body, that, in proportion to their weight, 200 times as much blood passes through the kidneys as circulates through the rest of the body generally.

The Renal Veins commence in the *capillary* network of the kidney, and, after repeated junction and anastomosis, terminate in one *efferent* trunk termed the *renal vein*.

The Ureters are two very dilatable tubes, each of which is about eighteen inches long and about the diameter of an ordinary quill. Their function is to conduct the urine from the kidneys into the bladder; they penetrate the exterior wall at the base of the bladder, and after running very obliquely for about an inch, open into the interior by two slit-like apertures.

The Bladder is a hollow conical bag which receives the urine as it leaves the ureters (see Fig. 46). It, like the stomach, consists of four coats:—1, a *serous* external coat; 2, muscular; 3, a fibrous or submucous coat; 4, an internal mucous coat. It is so *contractile* that, when empty, it presents scarcely any internal cavity; yet, when distended, is capable of holding 9 to 12 pints of liquid, in which case its walls become exceedingly thin and liable to fracture. If the bladder be ruptured or otherwise injured, so that any of the *urine* escapes into the adjacent tissues, death usually follows; *urea*, the principal constituent of the urine, being a powerful blood *poison*.

The Function of the Kidneys is the *depuration* or cleansing of the blood by the *excretion* of the *urine*. The urine is an *aqueous* solution of the dead or disintegrated muscle, nerve, or other tissue. It is the vehicle by which the effete, wasted, broken-up, *nitrogenous* matter of the tissues is eliminated from

the system. The principal solid constituent of the urine is a nitrogenous substance termed *urea.* Professor Haughton states that the quantity of this substance daily excreted is greatly increased by *brain* work. He gives 400 grs. as the average quantity secreted daily by an ordinary labouring man, and 533 grs. as the quantity secreted by the hard-working *student* or professional man.

The importance of the thorough elimination of these effete nitrogenous products of the *dead* tissues is shown by the *extent* of the *excreting* surface which nature has provided for its removal. It has been estimated that the *secreting* surface of the *tubuli* of the kidneys is *six* times as extensive as that of the *skin.*

The Urine is a pale yellow, slightly *acid,* fermentable liquid, which possesses a feeble but peculiar odour. Its sp. gr. is about 1·02. According to Dr. Parkes, the average quantity secreted per day by a male adult is about 52 fluid ounces. The quantity secreted during winter in *cold* or *damp* weather is greater than that secreted during summer in *hot* or *dry* weather, when the skin is most active. After some time the urine ferments, becoming *alkaline* (the *urea* being decomposed into *carbonate of ammonia*), and giving off a powerful *ammoniacal* odour.

The principal solid constituents of the urine are *urea* ($C_2H_4N_2O_2$), *uric,* and *lithic* acids; minute quantities of *creatine, creatinine,* and certain sulphates and phosphates are also found in the urine. The *urea* and *organic* constituents are derived from the *nitrogenous* tissues; the phosphoric and sulphuric acids are probably formed by the *oxidation* of the *sulphur* and *phosphorus* of the tissues. It has been estimated that a man daily loses 1-40th and a child 1-20th of his weight by the action of the kidneys.

The following table by Professor Miller gives the composition of healthy urine of sp. gr. 1·020 :—

COMPOSITION OF HEALTHY URINE.

				In 100 parts of *solid* matter.
Water			956·80	
Solids, 43·2.	Organic matters, 29·79.	Urea	14·23	33·00
		Uric acid	·37	·86
		Alcoholic extract	12·53	29·03
		Watery extract	2·50	5·80
		Vesical mucus	·16	·37
	Inorganic matters, 13·35.	Chloride of sodium	7·22	16·73
		Phosphoric acid	2·12	4·91
		Sulphuric acid	1·70	3·94
		Lime	·21	·49
		Magnesia	·12	·28
		Potash	1·93	4·47
		Soda	·05	·12
			999·94	100·00

Urea ($C_2H_4N_2O_2$), the principal organic constituent of urine, is a transparent, colourless, soluble, crystalline substance, which may be extracted from the urine by the action of nitric or oxalic acid ; nitrate or oxalate of urea is thus formed, the *urea* of which may be easily separated by the addition of carbonate of lime or baryta. Urea is *neutral* to test paper, but readily combines with most *acids*. Urea is not formed, but simply separated from the blood by the kidneys.

Uric or **Lithic Acid** ($C_{10}H_4N_4O_6$), which is a purely *excrementitious* product, constitutes but a very small portion of human urine, but exists in considerable quantities in the urine of some of the lower animals, particularly in the solid urine of serpents, from which it is generally prepared. It is deposited in crystals when hydrochloric acid is added to the concentrated urine. When pure it is a white, crystalline, nearly insoluble acid powder. *Hippuric* acid displaces *uric* acid in the urine of the horse and cow.

When *uric* or *lithic* acid is in excess in the urine it tends to form *gravel* and *stone* or *urinary calculi* in the bladder. It also collects in the joints of *gouty* patients, forming, in combination with *soda*, concretions known as *chalkstones*.

Creatine ($C_8H_9N_3O_4 + 2HO$), a constituent of the urine, was discovered by Liebig in the juice of flesh ; it has also been discovered in the blood. About 4 grs. per day are excreted in

the urine. When pure it forms colourless, transparent crystals, slightly soluble in cold, but readily soluble in hot water.

Creatinine ($C_8H_7N_3O_2$) has also been discovered in the juice of flesh. About 7 grs. are daily excreted in the urine. It may be prepared by the action of strong acids on creatine. It is a powerful *organic base*, and when pure forms colourless prismatic crystals, has an *alkaline* reaction, and is soluble in water.

Urea a Test of Work.—Not only is the quantity of *urea* and *uric* acid eliminated by the kidneys a *test* of the quantity of *nitrogenous* food daily required, but it is also a *test* of the amount of useful or *dynamical* work actually performed by the animal body. This subject is treated in a most interesting and instructive manner by Dr. Playfair in a paper recently published, entitled "The Food of Man in Relation to his Useful Work." In it he shows that the quantity of *urea* and *uric* acid eliminated affords a true *exponent* of the *dynamical* or useful work of the body.

An average man in a state of quietude living on mere subsistence diet excretes 263 grs. of *urea* daily. Soldiers in time of peace working moderately (equivalent to walking seven miles per day) excrete 575 grs. per day. A hard-working labourer (whose work is equivalent to walking twenty miles continuously) excretes 735 grs. daily. Professor Christison, when a young man, in order to ascertain the relation of *work* to quantity of *urea* excreted, worked two days as a carpenter, and walked (additionally) each day ten miles at the rate of about five miles an hour; he passed on an average 840 grs. of *urea* per day. Dr. Hammond, who exercised himself in a similarly laborious manner, excreted 865 grs. of *urea* per day. Dr. Playfair states that the average quantity of *urea* excreted by two blacksmiths on ordinary working days was 686 grs., but that on Sundays or days of *rest* it fell to 499 grs.

Dr. Haughton gives the following equations as representing the amount of the mechanical, mental, and vital work of the body indicated by the respective quantities of *urea* :—

Mechanical work (or 15 lbs. raised one mile)	= 136·5	grs. of urea.
Mental work (or five hours' study)	= 217·0	,,
Vital work	= 297·0	,,
	650·5	,,

Want of space precludes our entering further on this interesting subject.

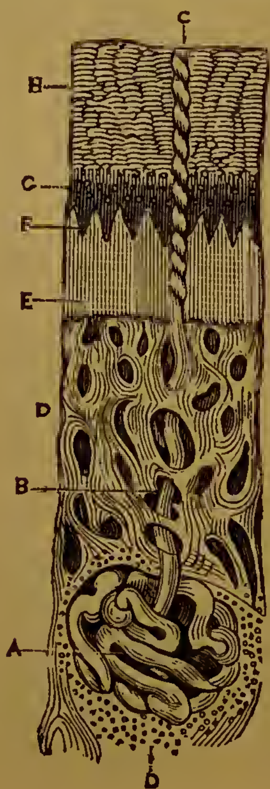
THE STRUCTURE AND FUNCTIONS OF THE SKIN AND ITS APPENDAGES.

The Skin forms the outer integument of the body. It covers the *whole* of its exterior, and with some slight modification, not materially affecting the plan of its structure, passes into its interior, and, in the form of *mucous* membrane, lines the whole of the *alimentary canal.* Upon the health and appearance of the skin depends to a very great extent the beauty and comeliness of the human body.

Structure of the Skin.—The skin is a complex membrane, consisting of three coats or layers:—

Fig. 49.—SECTION OF SKIN.

A. Sudoriparous gland.
B, C. ,, duct.
D. Subcutaneous cellular and adipose tissue.
E. Cutis.
F. Papillæ.
G. Rete mucosum.
H. Epidermis.



1, the *cuticle*, or outer layer; 2, the *basement* membrane; 3, the *cutis*, or true skin. It is very abundantly supplied with *sudoriparous* and *sebaceous* glands and *ducts*, and in many parts is extensively excavated with *hair follicles*.

The Cuticle, Epidermis, or **Scarf-skin,** forms the outer layer of the skin; it contains neither *bloodvessels* nor *nerves*, and is therefore quite insensible. This may be shown by passing a needle through it, the process neither causing *pain* nor *bleeding:* it is this portion of the skin which is raised when a *blister* is formed. Its chief functions are—1, to protect the *true* skin from *dirt* and the action of the *atmosphere;* 2, to confine *evaporation* to the *pores;* 3, to lessen the *sensitiveness* of the *true* skin. Its importance in this latter respect is shown by the intense smarting which is excited when a hard or pointed object is brought into contact with any *abraded* portion of the skin.

The *cuticle* consists of a *pavement* formed of several layers of *epithelial* or epidermic cells resting on the *basement membrane.* The cells forming the outer layer of the *scarf*-skin are dry, thin, flat, and horny, and are continually rubbing off; they form the scurf or *dandriff* which collects about the head, the hair preventing their escape, as in other parts of the body. This continued loss of dried cells by *desquamation* is repaired by the equally continuous growth or reproduction of new underlayers of *nucleated* cells formed out of the *liquor sanguinis* which *exudes* from the surface of the *cutis.*

Pores of the Skin.—The surface of the skin is penetrated by about 7,000,000 perspiration tubes or *ducts*, which open obliquely on the surface of the cuticle. The *mouths* of these tubes form the *pores* of the skin from which the perspiration exudes. If the surface of the skin be not frequently washed, these *pores* become obstructed, the process of *excretion* is partly arrested, and more or less of the dirt and poisonous organic matter is *absorbed* into the blood.

The Basement Membrane is an almost invisible layer of transparent, homogeneous, structureless membrane of extreme *tenuity*, which overlies the *cutis*, and supports the layer of *epithelial* cells forming the *cuticle.*

Rete Mucosum.—The colour of the skin of the negro and other races lies in the *lower* and newly formed layers of cells in the *cuticle*. These layers contain a number of *pigment* cells, which impart to the skin its distinctive *colour*. They were formerly imagined to constitute a distinct layer, which was termed the *rete mucosum*.

The Cutis, Dermis, Corium, or True Skin, lies immediately under the *cuticle*, the latter being everywhere moulded to it. It consists—1, of a compact layer of *areolar tissue;* 2, of a network of *capillaries;* 3, of a network of *nervous* fibrils; 4, of a network of *lymphatics* or absorbents; 5, of *adipose* (fat) tissue; 6, it is supposed to contain muscular fibre; 7, it contains millions of *sudoriparous* (sweat) glands; 8, it also contains *sebaceous* (oil) glands. The *cutis* is attached to the parts below by *areolar* tissue.

The *dense areolar framework* which constitutes the greater portion of the *true* skin consists of a *network* of *white* and *yellow* fibre. The former is most abundant where the skin is comparatively fixed, but where much *motion* or *extension* is required the latter predominates. The *elasticity* of the skin depends upon the presence of the *yellow* elastic fibrous tissue. If the *true* skin is well macerated in *acetic* acid the *white* fibrous element dissolves out, leaving the *yellow* fibre in diamond-shaped meshes. Areolar tissue is composed principally of gelatin; the true skin is therefore readily converted into *leather* by the process of *tanning*. At King's College Museum is exhibited a curious specimen which consists of a piece of good leather tanned from the skin of *Bishop*, the notorious murderer, who was executed many years ago at the time when "*burking*" was prevalent. Little closed spaces, or *bursæ*, to facilitate its movements, exist under the skin, at the *joints*, over the prominent points of the bones.

Capillaries of the Cutis.—The cutis is a very *vascular* organ—that is, it is very abundantly supplied with *bloodvessels*. The *arteries* immediately below the skin break up into a number of very minute *capillaries*, which *ramify* through the meshes in the *areolar* tissue, forming a very close *vascular* network. These *capillaries* lie so close to each other, and are so abundantly supplied with blood, that it is impossible even to insert the point of a fine needle into the *cutis* without *rupturing* their walls and

causing them to *bleed.* A distinct microscopic *capillary plexus*, or network, also surrounds each of the *cutaneous glands*. Each terminal *nervous* fibril is also supplied with its *capillary* vein and artery. When the surface of the skin is chilled the *capillary* tubes *contract*, and their blood is driven into the interior of the body, which thus becomes overloaded, and, if weak or delicate, suffers injury; while the skin, being deprived of its proper quantity of blood, is imperfectly *nourished*, and the *sudoriparous* glands are unable to proceed with their duty of *purifying* the blood, which thus becomes impure. The *nerves* also lose more or less of their *sensibility*, as every schoolboy knows who has experienced the *numbness* in the hands or fingers consequent on snowballing.

Nerves of the Skin.—The skin is abundantly supplied with *nerves*, the branches of which, like the capillaries, *ramify* through *meshes* in the *areolar* framework. They are distributed so extensively and *closely* through the skin that it is impossible to puncture the *true* skin without causing *pain.* Most of the *nervous* fibrils pass up to the *surface* of the *true* skin and terminate in little *looped* extremities, giving rise to the formation of *papillæ.*

Relative Sensibility of the Skin.—The skin in different parts of the body possesses different degrees of sensibility, those parts being most *sensitive* which are most abundantly supplied with *nerves.* The most *sensitive* parts in the surface of the body are the point of the *tongue* and centres of the *lips;* they are much more sensitive than the tips of the finger. The relative *sensibilities* of the different parts of the skin may be proved by the following simple experiment :—Take a pair of drawing compasses, with their points slightly blunted, and apply them to different parts of the skin. The following table shows the respective distances at which the *two* points may be distinguished at the different parts. At less than the given distances the *two* points appear as though they form but one point :—

Table showing Sensibility of Skin.

Point of tongue . .	½ line.	Palm of hand . . .	5 lines.
Tip of finger	1 ,,	Forehead	10 ,,
Red surface of lips .	2 lines.	Back of hand . . .	14 ,,
Tip of nose	3 ,,	,, thigh . . .	30 ,,

Papillæ of the Skin.—If the skin of the finger or the palm of the hand be carefully examined it will be observed to be marked with little curvilinear *rows* of *elevation*, separated from each other by intervening *furrows* or grooves. The rows of *ele-*

vation are formed by minute *nerve loops* previously referred to, projecting above the rest of the surface. The cuticle which lines their surface dips in between these rows of *papillæ* and gives rise to the *grooved* marking referred to. The *papillæ* are most numerously distributed to the palms of the hands, the tips of the fingers, the *lips*, and the *tongue*. In the latter they have not the same regular arrangement that they have in the former.

Structure of the Papillæ.—When the cuticle is removed the *papillæ*, as shown in the diagram, consist of a number of minute conical bodies. They are about 1-100th of an inch in height and 1-250th of an inch in diameter. They are composed of a central *nerve* loop fibril, and of a *capillary* vein and artery invested externally by the *basement* membrane. The *papillæ* really constitute a prolongation of the *true* skin into the substance of the *cuticle*. (See F, Fig. 49.)

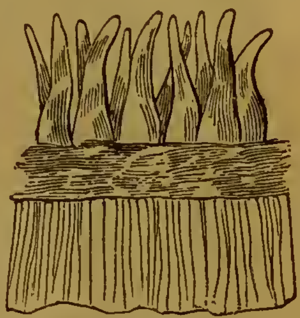


Fig. 50.—Dermis and Papillæ of Foot.

In addition to the parts just mentioned the *papillæ* of the most highly *sensitive* surfaces are found to contain a minute, microscopic, hard, solid, oval body, termed the *axile body*, or *tactile corpuscle*. These bodies occupy the centre of the papillæ; they receive the end of the *nervous* fibrils, which, in some cases, pass up their centres and terminate in their axes, but in others wind round their circumference. They very much resemble the *Pacinian corpuscles* in their structure. Professor Huxley regards them as composed of modified *neurilemma*.

Their function is not well understood; but they are supposed, as in the case of the *otolithes* in the ear, to render sensation more *acute*.

It has been calculated that upwards of 2,400 *papillæ* exist in one square inch of skin on the tips of the fingers.

The *papillæ* in some parts of the skin, as on the *tongue*, are not *conical*, but variously shaped.

The Skin a Respiratory Organ.—The skin *absorbs* oxygen and *exhales* carbonic acid gas. This may be proved by confining the human body in an oiled silk bag fastened round the neck. The residual air in the bag will be found, on careful analysis, to contain *less* than its ordinary proportion of *oxygen*,

but a considerable *excess* of *carbonic acid* will be present.

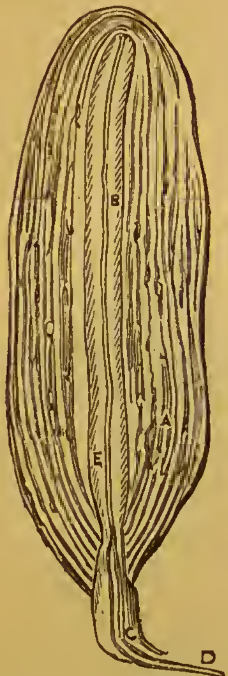


Fig. 51.—A Pacinian Corpuscle.

If the skin of a frog be covered with a thin coating of varnish it will die with all the symptoms of *suffocation*, or, as it is termed, of *cutaneous asphyxia*. It has been variously estimated, as the result of experiment, though apparently of no great accuracy, that the quantity of carbonic acid gas *exhaled* from the *skin*, as a breathing organ, equals 1-100th to 1-40th of that *exhaled* by the *lungs*. The importance of bathing and extreme cleanliness is therefore manifest. It has been observed that the *livid* hue that attends death by *suffocation* sometimes gives place to the fresh pink hue of health, caused by the action of the *oxygen* absorbed through the *skin* into the superficial *capillaries*.

The Perspiratory Function of the skin is its most important function. By means of this function the skin both *purifies* the blood and *regulates* the animal heat. It is effected by means of the *sudoriparous* glands to be presently described. *Perspiration* is *always* being *exhaled* from the skin in the state of *invisible* vapour; this is termed *insensible* perspiration. This may be proved by bringing the hand or any part of the body into contact with a bright polished metallic surface, when its lustre will be immediately dimmed by the *condensation* of the invisible *vapour* passing from the skin. When the perspiration is secreted and passed to the surface of the skin more *rapidly* than it *evaporates* it collects in the form of *liquid*, and is then termed *sensible* perspiration.

The quantity of perspiration secreted daily varies with the health, the temperature and moisture of the air, the amount and degree of exercise, and the quantity of liquid drunk; also with the activity of the *lungs* and the *kidneys*, more especially the latter. The quantity of *perspiration* daily *excreted* by puddlers, glass-blowers, and furnace men is scarcely credible. According to Dr. Southwood Smith's experiments at the Phœnix Gas Works, certain gasmen employed at the furnace lost upwards of 5 lbs. in weight in the course of 70 minutes. The average daily quantity of *insensible* perspiration secreted is estimated at about 2 lbs. This contains about 140 grs. of solid matter. The solid matter does not increase in the same ratio as the liquid secreted. In summer the quantity of the *perspiration* excreted exceeds that of the *urine;* in winter, on the contrary, the quantity of urine *exceeds* that of the perspiration.

Perspiration.—Liquid perspiration, or sweat, is a transparent, colourless, and slightly acid liquid, having a peculiar *odour* according to the part of the skin from which it is obtained. It is slightly turbid, from the presence of *sebaceous* matter and *epidermic* scales, which form 2-10ths to 3-10ths per cent. of the solid portion of the excretion. Sweat obtained from the feet and armpits is sometimes slightly *alkaline.* The relative proportion of its solid constituents varies from 0·5 to 1·25 per cent., according to circumstances previously indicated. Its *acidity* is due chiefly to the presence of *lactic* and *formic* acids; *acetic* and *butyric* acids are also present.

The importance of this *excretion* is shown by the fact that the presence of *lactic* acid in the blood is the probable immediate cause of *rheumatism.* It can always be detected in the blood of *rheumatic* patients. The following experiment also tends to show the relation of *rheumatism* to the presence of *lactic* acid:—Inject *lactic* acid into the veins of a dog or cat; in the course of a short time all the symptoms of severe *rheumatic* disease will set in, and if the animal be examined after death all the peculiar internal marks of the disease, especially those about the *heart* and *joints*, will be manifested.

During severe bodily labour much *lactic* acid is developed in the system. Damp or cold, acting upon the *skin*, tends to *check* its action, and therefore to favour the accumulation of *lactic* acid in the body; hence their influence in developing *rheumatism* among agricultural and other poorly fed out-of-door labourers.

The perspiration contains a peculiar *azotized* substance exceedingly prone to decomposition.

The following table shows the proximate—

COMPOSITION OF PERSPIRATION.

Water	995·00
Animal matter with lime	0·10
Sulphates, and matters soluble in water . .	1·05
Chlorides ,, ,, . .	2·40
Acetic acid, chlorides, acetates, lactates, and alcohol extracts	1·45
	1000·00

Sudoriparous Glands (from L., *sudor*, sweat, and *paro*, I prepare).—The sudoriparous or sweat glands are minute *tubular* glands diffused through the skin in enormous numbers, which *excrete* the *perspiration* from the blood. They also *exhale* minute quantities of *carbonic acid* and nitrogen gases.

They are small, *lobular*, reddish bodies, consisting of coiled or *convoluted* tubes, terminating in *efferent* ducts. The *tube* composing the *gland* is about 1-1,700th of an inch in diameter. Sometimes several tubes, formed by *dichotomous* division (dividing in twos, from Gr., *dicha*, in two parts, and *temno*, I cut), enter into the structure of the gland. But no gland has more than one *efferent* duct. The *duct* as it leaves the *gland* is more or less *spiral;* as it passes the *papillæ* it becomes *straight;* but on entering the cuticle it again becomes *spiral* or corkscrew-like, terminating obliquely in its surface, as previously described.

Fig. 52.—SUDORIPAROUS GLAND.

The *tubes* of which the sweat glands and their *ducts* are composed consist—1, of an outer layer of *basement* membrane continuous with the *basement* membrane which lines the surface of the *papillæ;* 2, of an *inner* layer of *epithelial* cells continuous with those of the *epidermis*. The terminal

portion of the *sudoriparous* duct therefore contains no *basement* membrane, but it is a little wider than the rest of the *duct*, being about the 1-1,500th inch in diameter. Each *sweat gland* is surrounded by its own *plexus* of *capillaries*.

It has been estimated that there are, on an average, about 2,800 *pores* in each square inch of the skin; also that there are about 2,500 square inches of skin on the *surface* of the body. There are, therefore, upwards of 7,000,000 *sudoriparous* glands with their ducts. The *tube* of each gland is about one-quarter inch in length; if united they would extend a distance of twenty-eight miles. The perspiration *tubing* thus forms twenty-eight miles of *sewerage* for draining away the *impurities* of the human blood. The extent of these preparations for its purification should enable us to form some idea of the great importance of daily ablution or *bathing* as a means of health.

The Sebaceous or Fat-forming Glands (from L., *sebum*, fat) are little *sacculated* glands which *secrete* a *fatty* or oily substance for lubricating the skin and preventing its drying and cracking. They are most abundantly diffused on the *scalp* and those parts of the body supplied with *hair*, and generally open into hair follicles. They do not exist in the palms of the hands and in those parts of the body which are not supplied with hairs. Some of the largest exist on the face, and particularly on the nose. When the *orifices* of their *ducts* are obstructed, little black specks are formed by the dirt sticking on the surface. If these black specks be squeezed between the nails little white worm-like bodies are expelled; these consist of little cylindrical masses of the *sebaceous* secretion, which acquire their *shape* from the orifice through which they are squeezed. Though they are not, as is popularly supposed, little worms or maggots, yet they generally contain little *entozoa*, or parasitic worms, of the species termed *acarum folliculorum*.

The *sebaceous* glands are exceedingly active in the natives of hot climates, especially in the negro; the intense heat of the sun's rays requiring them to have additional protection to keep their skins moist and flexible. To the great activity of these glands is due the peculiar *odour* of the negro.

The *sebaceous* glands consist of a *follicle* or bag, the walls of each *follicle* containing two or more deep indentations or *saccules.* The number of these depressions or *sacculi* varies from two to twenty in the different glands. The *meibomian* glands, in the free borders of the eyelids, are slightly modified *sebaceous* glands.

The walls of each gland are formed—1, of an *outer* layer of *basement* membrane ; 2, of an *inner* layer of *epithelial* cells.

Hair and Baldness.—Hairs are peculiar modifications of the *cuticle.* They exist on nearly all parts of the surface of the body. except on the palms of the hands and the soles of the feet. They vary in colour and other characteristics in various parts of the world, and form one of the distinguishing features of *race.*

Hairs are set obliquely in little depressions or *follicles* in the true skin, termed *hair follicles.* At the bottom of each *hair follicle* is a minute projecting body, the *hair papilla,* upon the health and vitality of which depends the *growth* of the hair. Each *papilla* is supplied with the *blood* necessary for its *nutrition* and for the *growth* of the hair by a minute *capillary* artery. When its circulation is *enfeebled* or arrested the *growth* of the hair suffers or entirely ceases, producing *baldness.* If the *baldness* has been of *long* duration, the mouths of the *hair follicles* become closed up and it becomes incurable. In its *early* stages it may sometimes be removed by raising the general tone of the health, and thus increasing the *vigour* of the *circulation,* and promoting the circulation in the *arteries* of the hair *papillæ* by applying *stimulating* washes and repeated *friction* to the scalp. All applications to the hair alone are quite useless.

Structure of the Hair.—A single hair consists of a long conical fibre. It has a *root,* a *shaft,* and a point, and contains an outer layer termed the *cortex,* and an inner or *medullary* substance. The *root* of the hair is the whitish, bulbous enlargement at its lower extremity, by which it is inserted into the *hair follicle ;* it is attached to and surrounds the *hair papilla.* When a hair is pulled out by its root it is detached from the *hair papilla* and *follicle,* taking with it its circular lining, termed its root-sheath, and it will be reproduced so long as the *papilla* remains healthy and uninjured.

The *cortex* or outside layer of the hair consists of *imbricated* scales (from L., *imbrex,* a tile) ; that is, of scales which overlie each other like the tiles or slates of a roof.

The *medulla,* or interior substance of the hair, consists towards its root of little soft roundish cells, some of which contain the *pigment* cells to the presence of which the *colour* of the hair is due ;

higher up in the shaft these cells become elongated and developed into fibres.

The Nails are the flattened, elastic, horny, protective coverings placed on the backs of the ends of the fingers and toes. They are also composed of modified *epidermic* cells. Each nail has a *root*, a *body*, and a *free edge*. The *root* is inserted into a groove or fold in the cutis, the *body* is the exposed part of the nail, and the *free edge* is formed by its anterior extremity.

The nails aid *sensation* by offering a resisting medium to the ends of the fingers, by which they are brought into more perfect contact with the body touched.

The Skin Regulates the Animal Heat.—The normal temperature of the human body is 98° to 100° F. An increase of 12° or 13° above this point always produces death. In fever the temperature of the blood sometimes rises to 106° or even 110° F.

The skin acts vigorously at *high* temperature, in a dry atmosphere. A person may endure a temperature of 200° to 300° F., or even higher, in a *dry* atmosphere, for some time, without injury, in consequence of the vigorous *perspiratory* action of the skin, the *cooling* influence of which counteracts the effect of the *high* external temperature. If, on the contrary, the heated air is charged with *moisture*, the *refrigeratory* action of the skin is checked, and such a temperature would not only be quite insufferable, but would speedily prove fatal if it were attempted to remain in it.

The workmen of the late Sir F. Chantrey, the celebrated sculptor, were accustomed to enter the furnace in which they dried their moulds when the floor was *red hot* and the atmosphere at 350° F. The "Fire King" was in the habit of entering an oven heated to from 400° to 600° F., taking with him a *rump steak*, which, it is said, he *cooked* and *ate* while in the oven : the only precaution he took being to prevent any part of his body coming into contact with the heated surfaces, by clothing his feet and hands with *bad* conducting material.

Liquid water in its conversion into vapour absorbs, or converts into *latent heat*, caloric that would otherwise have raised its temperature nearly 1,000° F. If two similar copper vessels be placed on the fire—the one containing *water*, the other *empty*,—the bottom of the *latter* will soon become red hot, while the former will only acquire the same temperature as the boiling

water (212° F.). Yet equal quantities of heat will pass from the fire into each vessel ; but in the case of the first vessel the *excess* of heat will be *absorbed* by the water in its conversion into *steam*, and carried off by it in the form of *insensible* or *latent heat.* It is by this conversion of *sensible* into *latent* heat that the skin exercises its *cooling* or refrigeratory power.

The influence of *moisture* in *checking* the *perspiratory* and cooling action of the skin is shown in the comparative action of a Turkish or hot-air bath and a Russian or vapour bath. In the former *dry* air bath a very *high* temperature may be borne for a considerable period without inconvenience ; in the latter *moist* bath a much *lower* temperature can be borne for a short time only. A vapour bath at 120° F. cannot be endured for more than ten minutes without intense discomfort ; the vapour with which the bath is charged greatly diminishing the *cooling* influence which the *skin* exerts on the body.

The power of a Turkish bath to relieve the effects of a severe incipient *cold* is in some cases almost miraculous, and depends on its power to restore vigorous *cutaneous* action ; but it should be used with caution, and never taken without medical advice by persons labouring under any tendency to brain or heart disease.

ANIMAL MECHANICS.

The Osseous System.

Animals are classified by means of their *skeleton* into two *sub-kingdoms*, termed respectively the *Vertebrata* and the *Invertebrata*, accordingly as they possess or are wanting in certain bones termed *vertebræ.* In many of the lower animals the bony fabric is collected principally on their *exterior*, forming an *exoskeleton;* but in all the higher animals, including man, the bony framework of the body is placed in the *interior*, forming an *endoskeleton.*

The Skeleton (from Gr., *skello*, I dry), or bony framework of the human body, is one of its most characteristic structures, and consists of 249 variously shaped bones. The *moveable* bones are, in general, tipped with *cartilage* or gristle to prevent friction, and

are united into one system by means of certain tough membranous bands termed *ligaments* (from L., *ligo*, I bind).

A A′. Vertebral column supporting cranium.
R. Costæ or ribs.
X. Sternum or breast-bone.
Y. Clavicle or collar-bone.
B. Humerus or bone of upper arm.
C. Elbow.
D. Radius.
E. Ulna.
F. Carpal or wrist-bones.
G. Phalanges or bones of the fingers.
S. Os innominatum } forming the
W. Os sacrum . . } pelvis.
H. Head of the femur.
I. Os femoris or thigh-bone.
L. Patella or kneepan.
M. Tibia.
N. Fibula.
O. Tarsal or ancle-bones.
P. Meta-tarsal bones.

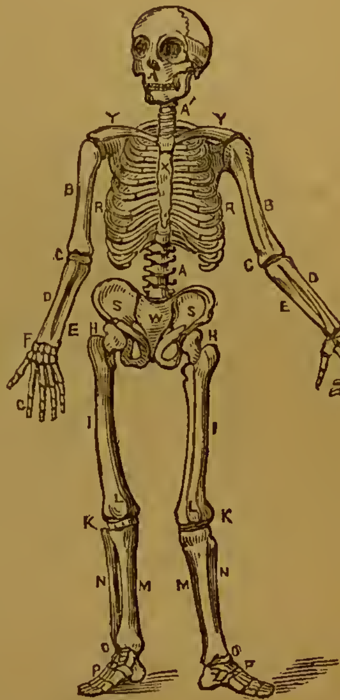


Fig. 53.—The Human Skeleton.

Functions of the skeleton { 1. To support various parts of the body. 2. To protect various parts of the body. 3. To act as passive agents of motion. }

Bone, as we usually see it, is a hard, dry, yellowish white, tough, inflexible, and very durable substance. In the *living* state, as it exists in the body, it is supplied with blood, and is of a decidedly pinkish colour. It is composed of *animal* or *organic* and *earthy* or *inorganic* matter. This double composition may easily be proved by the two following simple experiments :—

EXPERIMENT I.—Place a *weighed* bone in dilute *muriatic acid;* after some hours remove, wash, and again weigh it. It will be found to have *lost* about 2-3rds of its *weight*, and with it also to have lost its property of *inflexibility*, and, if a long bone, may be twisted into a knot. The acid has *dissolved* out its *earthy matter*, consisting chiefly of *tribasic phosphate of lime*, and rendered it *flexible.*

EXPERIMENT II.—Place a *weighed* bone in a clear bright red fire, which does *not smoke*, for half an hour or more. When the bone is thoroughly burnt, and all traces of *blackness* have disappeared, remove carefully, allow it to cool slowly, and again *weigh.* It will be found to have lost 1-3rd of its weight. Its *animal* or *gelatinous* constituent has been burnt away, and with it has disappeared its *toughness.* The hardness and inflexibility of bone is dependent upon the *mode of aggregation* as well as upon the constituents of the bone, since certain very *flexible* fish bones contain *more earthy matter* than *inflexible* human bone.

Bones in Infancy and Old Age.—The composition of bones varies very much at different periods of life. In infancy the quantity of earthy matter in the bones is very small, being less than 1-3rd of the weight of the bone. Properly speaking, *true* bone does not exist in the *skeleton* of an infant. In middle life the *earthy* matter constitutes about 2-3rds of the weight of the bone, while in advanced old age the quantity present in the bone is so great as to render it exceedingly brittle.

The bones of an infant will *bend* and *twist*, but will not *break.* On the contrary, a very aged person can scarcely fall without breaking a bone; and when broken, in many cases the bone will not reunite.

Bones are divisible, according to their shapes, into four classes—*long*, *short*, *flat*, and *irregular.*

The Long Bones are found chiefly in the limbs, where they act as agents of support, locomotion, and prehension. A long bone consists of a *shaft*, or long cylindrical portion, and *extremities*, which are generally expanded, the upper extremity termed the *head*, and the lower extremity, which is generally expanded, the *condyle.* The *shaft*, or long cylindrical portion of the bone,

is hollow, containing the *medullary canal*, which is lined by an internal *periosteum*, and filled with a fatty substance termed *marrow*. The walls of the *shaft* are formed of dense *compact* bony tissue.

The *extremities* of the long bones are formed of loose, spongy, or *cancellated* bony tissue, covered with a very thin outer layer or crust of *dense* osseous tissue. The extremities are in general expanded for the attachment of the *muscles* and *ligaments*. The principal *long* bones are the *Clavicles*, *Humeri*, *Radii*, *Ulnæ*, *Femurs*, *Tibiæ*, *Fibulæ*, *Meta-carpal* and *Meta-tarsal* bones, and the *Phalanges* of the toes and fingers.

The Short Bones, as those of the *wrist* and *ancle*, are composed of loose *cancellated* bony tissue, covered with a thin crust of *compact* bony substance. The cells or *interspaces* in the *cancellated* tissue are filled with *marrow*.

The Flat Bones are composed of two layers of *compact* bony tissue, enclosing more or less *cancellated* tissue, according to the thickness of the bone. The *flat* bones are the *Occipital*, *Parietal*, *Frontal*, *Nasal*, *Lachrymal* bones, the *Scapulæ*, *Innominata*, *Sternum*. and *Costæ*.

The Irregular or Mixed Bones are the *Vertebræ*, *Sacrum*, *Coccygis*, the *Temporal*, *Sphenoid*, *Ethmoid* bones ; the *superior* and *inferior Maxillaries*; the *Palate*, *inferior Turbinated*, and the *Hyoid* bones. Their shapes vary exceedingly, and cannot be defined by any general description. They also are mainly composed of *cancellated* bone, with an exterior thin crust of *compact* bone.

The student is strongly advised to make himself familiar with the names of the various bones, and their places in the skeleton, by repeatedly pointing them out on the diagram.

Periosteum (from Gr., *peri*, round, and L., *ossis*, a bone).—The bones are covered externally with a tough, fibrous, *vascular* membrane, termed the *periosteum*, which adheres to the whole of their surface, except their ends, or those portions tipped with *cartilage*. A finer modification of it also lines the interior of the *medullary* canals.

Functions of Periosteum.—1. It makes the surface of the bone smoother and thus lessens *friction*. 2. It affords a medium in which the *bloodvessels* break up or *ramify* before entering the minute orifices in the surface of the bones. 3. It serves as a medium of attachment for *ligaments*, *tendons*, and *muscles*.

When the *periosteum* of a bone is injured, that portion of the

bone is very liable to *necrosis*, or death, in consequence of its being deprived of the blood derived through the *periosteum*, which is necessary for its *nutrition*.

Bloodvessels in Bone.—The bones are abundantly supplied with blood by means of the *capillaries* which ramify in the *Haversian canals*. The capillaries in the *cancellated* interior of the bones are in some cases derived from arteries which enter at the small apertures seen at the ends of the bones. But more generally they are derived from the vessels which break up in the *periosteum* which invests the surface of the bone.

Repair of Broken Bones.—(See page 221.)

Marrow.—The *medullary* canal in long bones, and the *inter-spaces* in *cancellated* bone, are filled with a substance termed *marrow*. In adult bones the marrow in the *shaft* is of a yellow colour, and contains 96 per cent. *fat*, 1 *areolar* tissue and vessels, and 3 per cent. of fluid and extractive matter. In very young bones it is of a reddish colour, and contains 75 per cent. of water and 25 per cent. of solid matter, consisting of albumen, fibrin, extractive matter, and a *mere trace of fat*.

Nerves of Bone.—Nerves have not yet been discovered in the interior of bone, but of their existence there can be but little doubt, since many injuries and affections of the bones are exceedingly painful.

The bones of the *skeleton* have been divided into those of the *head*, *trunk*, and *extremities* or limbs.

The bones of the head include those of the *face* and skull, or *cranium*.

The Skull, or Cranium, is the oval or roundish shell of bone which *holds* and *protects* the brain and *medulla oblongata*. It consists of eight bones—one *frontal* bone, forming the forehead; two *parietal* bones, forming the roof, sides, and back of the head; two *temporal* bones, forming the temples; one *ethmoid* bone; one *sphenoid* bone, and one *occipital* bone, by which it is fastened to the neck. The three last-mentioned bones form the back and *base* of the skull. The *ethmoid* and *sphenoid* bones cannot be seen without dissecting the skull.

The back of the skull near its base is formed by the *occipital* bone. This bone contains a large aperture termed the *foramen magnum*, through which the *spinal cord* passes from the *brain*. On each side of the *foramen magnum* is situated a smooth projection termed the *occipital condyle*. These *condyles* are received into *two* corresponding smooth *cavities* in the upper surface of the

first cervical vertebra or neck-bone. This bone is termed the *atlas*. (See Fig. 56.)

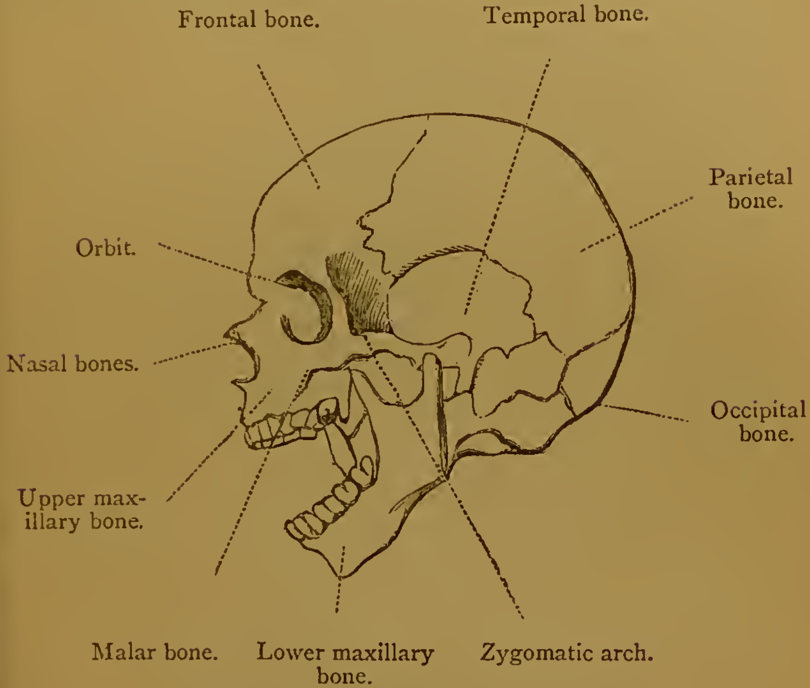


Fig. 54.—The Human Skull.

By means of this joint the head is moved upwards and downwards like a see-saw, as in the act of nodding. This arrangement makes it a lever of the *first* order, the atlas forming its *fulcrum*.

Diploe (from Gr., *diplous*, double).—Each of the wall-bones of the skull is composed of an inner and an outer layer of compact bony tissue, united by an intermediate layer of loose spongy bone termed *diploë*. The advantages resulting from this arrangement are—1, the greatest strength or resisting power is derived from a limited weight of bony substance; 2, a crack or injury received on its external surface is not so likely to extend to the interior as it would be if the whole plate was *homogeneous* in its structure.

The *outer table* of the skull is thicker and tougher than the inner one. The *inner table* is denser and more brittle than the outer one, and is therefore termed the *vitreous* table.

Sutures (from L., *suo*, I sew).—The wall-bones of the adult skull are immoveably fixed to each other by *serrated* or rather dove-tailed edges, the *teeth* of one bone fitting into corresponding indentations in its adjacent bone. These joints have, as shown in the diagram, a *sewed* or seam-like appearance, and have therefore been termed *sutures*.

The advantages resulting from the skull's being formed of several separate bones are—1, the bones grow from their edges, and are thus enabled to adapt themselves to the *growth* of the brain, becoming united when the brain has attained its full growth; 2, an injury received by one bone is less likely to extend to the surrounding parts than it would be did the whole skull consist of one undivided bone; just as the injury done to a window consisting of many small panes is more likely to be confined to a small surface than in the case of another window of similar size consisting of but one large pane of glass only.

The wings of the *sphenoid* bone at the base of the skull overlap the side wall-bones of the skull, and tend to hold them together like the beams of a roof.

When the edges really dovetail together, as the sides of a drawer are fastened by a cabinet-maker, they form *true sutures*; but when the edges simply overlap each other like fish-scales, they are termed *squamous* sutures, as in the case of the *temporal* bones.

The Orbits, bounded by the orbital plates, are deep, conical, hollow *cavities* or sockets, situated between the forehead and the cheeks. They *lodge* and *protect* the eyes, the *muscles* of the eyeball, the *lachrymal* glands, situated a little above the *outer* angles of the eyes, and the cushions of soft fat in which the eyes are packed to preserve them from injury.

The opening at the back of the orbits is termed the *optic foramen*; it gives passage to the *optic nerve*. At the inner angles of the eyes are two openings, one on each side, into the nose. These are termed the *lachrymal grooves;* they lodge the lachrymal *sacs* which pass the *tears* into the nose.

Bones of the Face.—There are fourteen bones in the face, viz.,—Two *malar* or cheek-bones; two *upper maxillary* or jaw-bones, each bone containing eight teeth; one *lower maxillary*, or jaw-bone, containing sixteen teeth; two *lachrymal* bones; two *spongy* bones; two *nasal* bones, forming the *bridge* of the nose; one *vomer* or ploughshare bone, which divides the nose into two cavities; and the two *palate* bones, forming the *roof* of the *back* of the mouth.

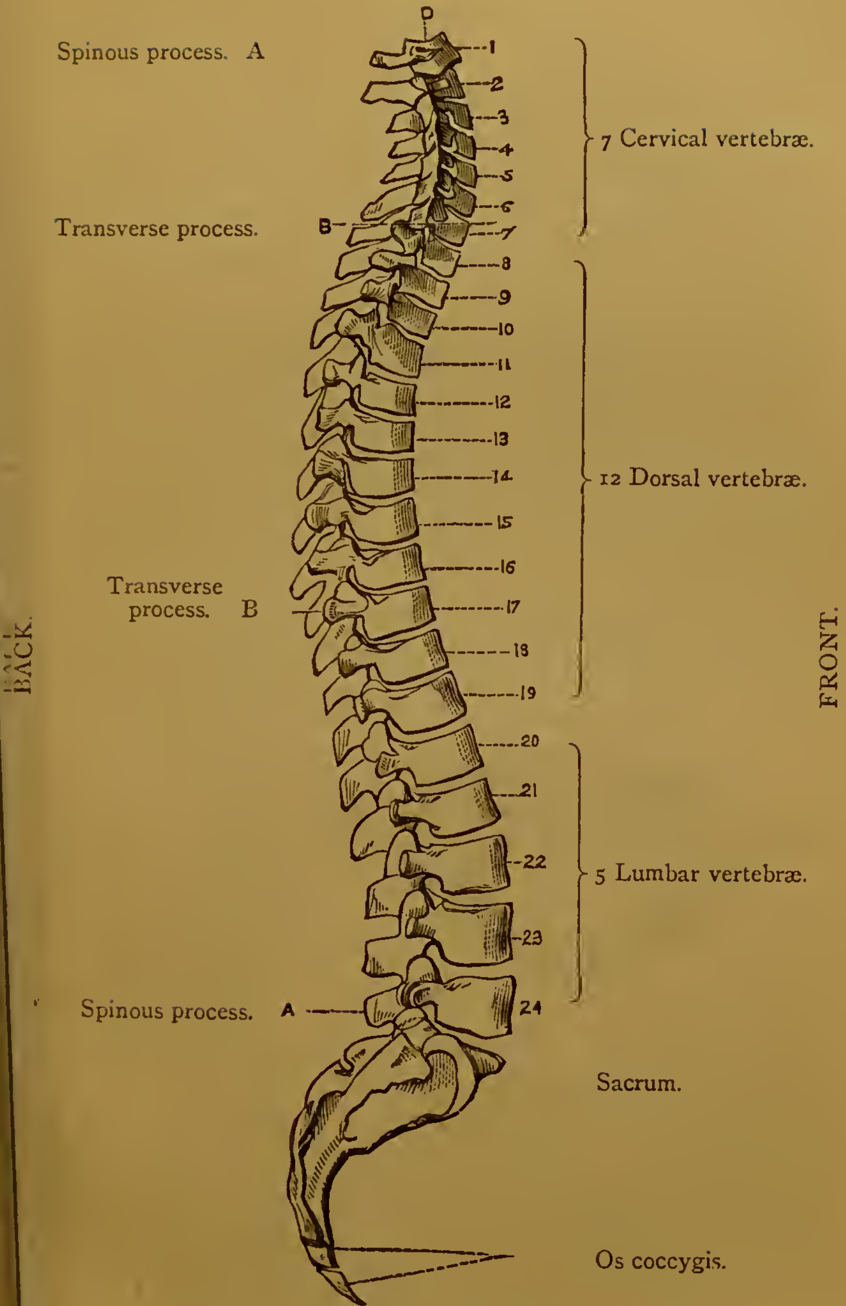


Fig. 55.—The Vertebral Column.

These bones form five *cavities*, in which are lodged the organs of *sight*, *smell*, and *taste*. The only *moveable* bone in the face is the lower jaw-bone.

The Bones of the Trunk comprise the *back-bone*, or *spinal column*, the *ribs*, the *sternum*, or *breast-bone*, and the *pelvis*.

The Vertebral or Spinal Column consists of twenty-four moveable *vertebræ*, between which are inserted pads or cushions of elastic *fibro-cartilage*; the *sacrum*, formed of five immoveable or fixed vertebræ; and the *coccyx*, consisting of four immoveable vertebræ.

The *bodies* of the twenty-four moveable vertebræ are connected together by layers or *pads* of *fibro-cartilage*, so as to form a continuous *flexible* column of the shape of a double S, capable of a considerable lateral or *turning* movement. Each *vertebra* contains a large hole or canal; these holes are also so arranged as to lie one on the top of the other, forming a continuous bony case termed the *vertebral canal*, in which the *spinal cord* is lodged and protected. These vertebræ are so arranged that each bone separately possesses but a very *limited* power of movement either in *bending* or *turning*; but the aggregate result of these individual movements is considerable. By this means the back-bone acquires great and sufficient mobility without *compressing* or damaging its enclosed *spinal cord*. Were it possible to bend the back, like the elbow, at a sudden angle, the enclosed *spinal cord* would be compressed, and *paralysis* or *death* would immediately follow. In consequence of the compression of the intervertebral pads of fibro-cartilage during the day, a person is not so tall at night as he is on rising in the morning.

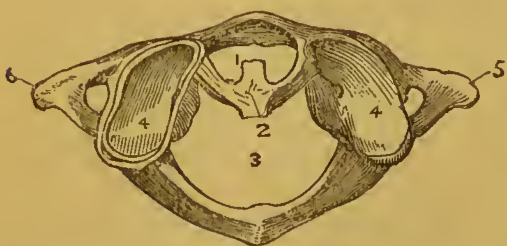


Fig. 56.—TOP OF ATLAS, OR FIRST CERVICAL VERTEBRA.

1. Anterior groove for dentate process.
2. Ligaments for keeping dentate process in place.
3. Spinal foramen.
4. Articulating surface.
5. Foramen for vertebral artery.
6. Transverse process.

The Atlas.—The first cervical vertebra is termed the *atlas*, in consequence of its supporting the head.

The most distinctive character of this bone is the absence of a *body*, the place of the *body* being occupied by a groove or space in its anterior arch, into which the *odontoid* process of the *axis* is fitted. This groove is separated from the vertebral canal by the transverse ligament, which passes behind the process, strapping it into its place.

The Axis, or second cervical vertebra, forms the *pivot* on which the head *turns*, or performs its *horizontal* or *lateral* rotating movement; hence it is termed the *axis* vertebra. (See Fig. 57.)

Fig. 57.—AXIS, OR DENTATE VERTEBRA.

1. Body. 2. Odontoid process. 3. Articulating surface. 4. Transverse process. 5. Lateral notch. 6. Foramen for vertebral artery. 7. Spinal process.

Its most distinctive character is the *dentate* or *odontoid* process, which consists of a strong prominent tooth-like process rising perpendicularly from the upper part of the *body* of the bone. This process fits into a corresponding groove in the front arch of the *atlas*, forming the *pivot* on which it rotates.

It is retained in its place in the *atlas* by small ligaments. These small ligaments are, especially in children, *easily* stretched or torn, and the bones consequently displaced, the result of which is *instant death*. Great care should therefore always be taken in handling the heads and necks of children—as, for instance, in drying them after bathing, washing, &c.,—lest serious consequences should follow.

Structure of a Vertebra.—A vertebra usually comprises

Fig. 58.—SIDE OF A VERTEBRA.

1, 2. Lateral notches. 3. Body. 4, 4. Articulating surfaces to receive heads of ribs. 7. Transverse process. 8. Articular cavity for tubercle of rib. 9. Spinous process. 10. Tuberosity of spinous process for insertion of muscle.

a *body* or *centrum*, which is attached to those of the adjacent vertebræ by a pad of *fibro-cartilage;* transverse and spinal processes for the attachment of the muscles which raise and support the back; a central opening, forming a portion of the vertebral canal, which receives and protects the *spinal cord;* certain *notches*, which are apposed to those of the adjacent

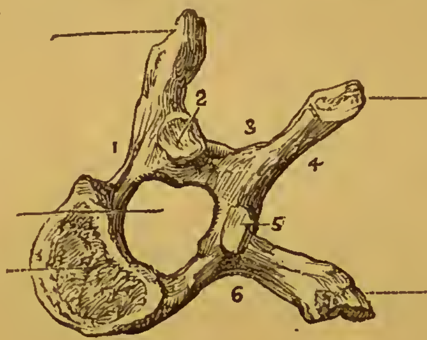


Fig. 59.—Top of a Vertebra.

vertebræ forming the intervertebral foraminæ, which give passage to the spinal nerves; and *articular processes* or facets, which help to connect them with the adjoining vertebræ. These parts are plainly shown in Figs. 58 and 59.

The Thorax is the bony, or rather osseo-cartilaginous cage intended to lodge and protect the heart and lungs; it forms the largest cavity in connection with the spine. (See Fig. 60.)

The back of the *thorax* is formed by the twelve *dorsal vertebræ* and a portion of the ribs; its sides are formed by the twelve pairs of *costæ*, or ribs; and its front by the ribs, the *costal cartilages*, and the *sternum*, or breast-bone.

The Costæ, or Ribs, consist of twenty-four long, thin, flat, elastic, arched bones, which are attached in pairs to the *dorsal vertebræ* behind, and to the *sternum*, by means of the costal cartilages, in front. The upper pairs are placed horizontally, but the lower ones are fixed obliquely, their anterior extremities pointing downwards. The capacity for enlargement of the chest, so essential in breathing, is due to the obliquity of the ribs. The spaces between the ribs are termed the *intercostal spaces;* they are filled by the intercostal muscles, which draw together and raise up the ribs. The elasticity and flexibility of the *costal cartilages* endow the walls of the chest with great

freedom of movement. The ribs are divided into seven *true ribs* and five false ribs. The *true* ribs, which form the upper part of the *thorax*, are *directly* connected with the *sternum* by means of their *costal* cartilages; hence they are also termed *vertebro-sternal ribs.* The five *false* ribs consist of three upper ribs, termed the *vertebro-costal ribs*, and two lower ones, termed

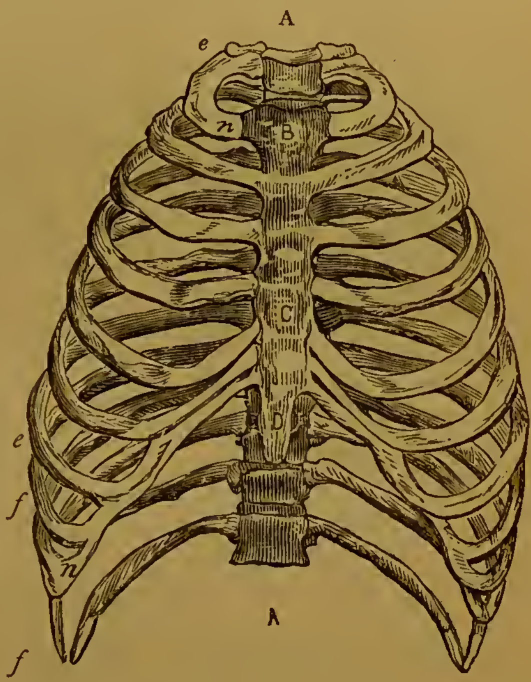


Fig. 60.—BONES OF THORAX.

A, A. Dorsal vertebræ.
B, C, D. Sternum.
B. Manubrium.
C. Gladiolus.
D. Ensiform cartilage.
e, e. True ribs.
f, f. False ribs, the two lower being free or floating ribs.
n, n. Ten pairs of costal cartilages.

the *floating* or *vertebral* ribs. The *vertebro-costal* ribs are attached posteriorly to the *vertebræ*, and anteriorly to the *costal* cartilages only, and therefore not directly to the *sternum.* The vertebral or *floating ribs* are attached to the *vertebræ* only, their anterior ends being *free.*

The Sternum, or breast-bone (see B C D, Fig. 60), lies in the middle of the front of the chest. It is a flat, narrow bone, consisting of three pieces. Its shape has been compared with that of an ancient sword: the upper bone, or *manubrium* (B), corresponding with its handle; the middle bone (C), or *gladiolus*, which represents the blade; and the lower cartilaginous extremity of the bone, termed the *ensiform appendage* (D), which is shaped like the point of the sword.

During youth the *ensiform appendage*, which may be felt with the hand, is very *flexible* and yielding. Care should therefore be taken not to press the front of the chest against the *desk* or the *table* while sitting, otherwise this bone will be pushed in, thus reducing the *capacity* of the *lungs* and the chest, thereby interfering with the purification of the blood and enfeebling the health. Some bootmakers have produced great depressions or cavities in their chests large enough to hold a human fist by the injurious habit of pressing the chest against the last.

The Pelvis (from L., *pelvis*, a basin) is the lower girdle of bones which bounds the lowest or *pelvic* cavity of the trunk. (See Fig. 53.) It consists of four immoveable bones, viz. :—the two *ossæ innominata* (from L., *in*, not, and *nomen*, a name), or nameless bones, so called because of their shapes bearing no resemblance to any other known object ; the *sacrum*, and the coccyx.

The Ossæ Innominata, or the hip-bones, consist of three parts, which in early life form separate bones, but are firmly united in the adult,—the *ilium*, hip, or flank bone ; the *ichium*, or sitting-bone, which supports the trunk in the act of sitting ; and the *pubic* bone.

The Acetabulum is the deep cup-shaped cavity or socket in the lower and outer part of the *innominatum*, or *hip*-bone, which receives the head of the thigh-bone.

The Obturator Foramen is a large aperture in the hip-bone which lessens the weight of the pelvis, and admits of the passage of nerves and bloodvessels, which derive their names from it.

The Bones of the Upper Extremities comprise the following :—the two *scapulæ*, or shoulder-blades, and the two *clavicles*, or collar-bones, which, though forming part of the trunk, are usually placed among the bones of the extremities, since it is by means of these that the upper extremities are attached to the trunk ; the two *humerus* bones, the two *ulnar* bones, the two *radii*, the eight *carpal* bones, the five *metacarpal* bones, the fourteen *phalanges* of the fingers. To these may be added the four *sesamoid* bones (from Gr., *sesamon*, a kind of small grain, and *eidos*, shape), little bones which are added to the tendons of the muscles of the thumbs and the great toes, also sometimes to the tendons of other muscles, to increase their power. Their number varies in different persons, being increased by great muscular exertion.

The Scapulæ, shoulder-blades, or spade-bones, are two

irregular-shaped, flattish, triangular bones, by which the arms are attached to the trunk. The *scapula* lies on a cushion of muscles situated on the side of the upper part of the *back* of the chest, and is connected with the outer extremity of the collar-bone, which keeps it in its place, by the *coracoid process.* (See Fig. 61.) Another process, termed the *acromium process*, guards the ball and socket shoulder joint against injury.

A long, high, bony projection, termed the *spine*, crosses its outer surface obliquely, forming two deep fossæ. At its outer angle it expands and forms the *glenoid cavity* (from Gr., *glene*, a shallow pit, and *eidos*, shape) or socket, into which the upper bone of the arm is inserted.

Fig. 61.—The Scapula.

1. The spine.
2. The acromium.
3. The coracoid process.

The Clavicle, or collar-bone (from L., *clavis*, a key), named from its supposed resemblance to an ancient key, is a long double-curved bone, in shape very much like the letter *ʃ*. It forms the front of the shoulder. Its inner extremity is attached to the *sternum*, its *outer* to the *acromion* process of the *scapula*. The two *scapulæ* act as *beams*, keeping the arms and shoulders out; they would otherwise fall in on to the ribs in the front of the chest. (See Fig. 31.)

The Humerus (L., shoulder), or bone of the upper arm (see Fig. 62), has a rounded head, which is inserted into the *glenoid* cavity; a slight constriction or *neck;* a *shaft*, and a lower extremity, having two expansions or *condyles*, also two cavities or depressions, corresponding with the heads of the bones of the *fore-arm*, with which it forms a *hinge* joint.

The Fore-arm, or lower arm, is formed of two nearly parallel long prismatic bones—the *ulna* and the *radius*. (See Fig. 63.)

The *ulna* (from Gr., *olene*, the elbow), or cubit, which is the larger bone, is attached to the *humerus* by a large process at its upper extremity, termed the *olecranon*, which forms the elbow. Behind this process is a large, deep, articulating concavity, termed

the greater sigmoid cavity, into which the humerus is inserted, forming a *hinge* joint.

The *radius*, or spoke-bone, is the outside bone of the fore-arm. It has a head, shaft, and lower extremity. (See Fig. 63.) The head, which is small, is attached to the *ulna* and the *humerus*.

Fig. 62.—The Humerus.

1. Head.
2. Greater tuberosity.
3. Outer condyle.
4. Radial head.
5. Inner condyle.

Fig. 63.—The Radius and Ulna.

1. Shaft of ulna.
2. Its olecranon.
3. Its lower exremity.
4. Shaft of radius.
5. Head of radius.
6. Lower extremity of radius.

Fig. 62.

Fig. 63.

Its lower extremity, which is very large, is attached to the hand by two of the *carpal* bones, the *scaphoid* and *semilunar*.

The Hand is divisible into three segments—the *carpus*, or wrist; the metacarpus, or palm; and the phalanges, or fingers.

The Carpal Bones comprise eight small bones united by ligaments, and are arranged in two rows. The upper row, proceeding from the outer or *radial* side to the *ulnar*, consists of the *scaphoid* (Gr., *scaphe*, boat), or boat-shaped bone; the *semilunar;* the *cuneiform* (L., *cuneus*, a wedge), or wedge-shaped bone; and the *pisiform* (L., *pisum*, a pea), or pea-shaped bone. The lower row, proceeding from the thumb in the same order, consists of the *trapezium*, the *trapezoid*, the *os magnum*, or great bone, and the *unciform* (L., *uncus*, a hook), or hook-shaped bone.

The Metacarpal Bones, which form the broad part or palm of the hand, consist of five long prismoidal bones, which are attached to the lower row of the *carpal* bones.

The Phalanges of the fingers consist of fourteen small long bones, arranged in three rows (see Fig. 53), the upper row being

Fig. 64.

Fig. 64.—The Os Femoris.

1. Shaft.
2. Head.
n. Neck.
3. Greater trochanter.
4. Lesser trochanter.
5. Outer condyle.
6. Inner condyle.

Fig. 65.—The Tibia and Fibula.

1. Shaft of tibia.
2. External tuberosity of head.
3. Internal tuberosity of head.
4. Internal malleolus.
5. Shaft of fibula.
6. Head of fibula.
7. External malleolus.

Fig. 65.

attached to the lower *metacarpal* bones. Each finger contains three phalanges; the thumbs contain two only. The upper phalange of each finger is attached to its corresponding metacarpal bone by a joint which allows it considerable freedom of motion in every direction. All the other *phalanges* are connected

by *hinge* joints, which permit of a backward and forward motion only.

The Bones of the Lower Extremities comprise two *femurs*, or thigh-bones ; two *patellæ*, or knee-pans ; two *tibia*, or shin-bones ; two *fibulæ*, or splint-bones ; seven *tarsi*, or ankle-bones ; five metatarsi, or instep-bones ; and the fourteen phalanges of the toes.

The Os Femoris, femur, or thigh-bone, is the *homologue* of —that is, corresponds in *structure* with—the humerus in the arms, and is the largest and strongest bone in the body. (See Fig. 64.) It has a *head*, *neck*, *shaft*, and lower extremity, with two *condyles*. The upper end of the *shaft* is furnished with two large bony protuberances, termed respectively the *greater* and *less trochanters*.

The *head* of the femur is large and globular, and contains a depression near its centre for the insertion of *ligamentum teres*, by which it is attached to the *acetabulum* in the pelvis.

The great trochanter (from Gr., *trecho*, I run) is a very large prominence on the outer side of the *neck* and *shaft*, which serves for the attachment of the *gluteus* and other muscles which pull the leg. The *lesser trochanter* is a similar but smaller eminence on the inner side of the *neck* and *shaft*, which serves a similar purpose.

The Patella, or knee-pan, is a flat triangular bone, which is situated in front of and protects the knee-joint. It is inserted in the *tendon* of the muscles, modifying their direction and increasing their power. It is usually classed as one of the *sesamoid* bones, belonging to the muscular or *tendinous* system.

The Tibia, or shin-bone, is a long, prismoidal, nearly vertical bone, situated at the front and *inner* side of the leg. (See Fig. 65.) Its upper extremity is very much expanded, to afford the surface necessary for its articulation with the *condyles* of the *femur ;* the lower extremity of the *shaft* also expands considerably, though in a less degree, to afford the surface necessary for its attachment to the *astragalus*, one of the bones of the ankle. The *crest* or prominence in front of the *tibia* forms the *shin*. It is somewhat sharp and angular, and hence causes the pain experienced from a blow in this region of the leg. The *tibia* supports the weight of the body.

The Fibula (L., *fibula*, a buckle, the buckle of the garter being usually worn over its head), splint-bone, or small bone of the leg, is a long slender bone, parallel to the *tibia*, to the upper and lower extremities of which it is immoveably fixed. (See Fig.

65.) It is situated on the *outer* side of the leg; its lower extremity is expanded, and forms the *outer* prominence of the ancle. It is *homologous* with the *radius* of the lower arm, but has not, like it, any rotatory movement on its adjacent bone.

The Foot supports the body, and is an organ of locomotion; it, like the hand, is divisible into three segments. These are the *tarsus*, or upper instep; the *meta-tarsus*, or lower instep; and the *phalanges*, or toes.

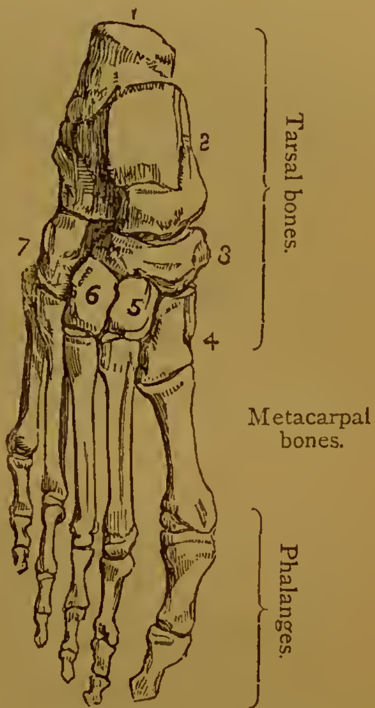


Fig. 66.—Bones of the Right Foot.

Upper Surface.

1. Os calcis.
2. Astragalus.
3. Scaphoid bone.
4. Internal cuneiform bone.
5. Middle ,, ,,
6. External ,, ,,
7. Cuboid bone.

The Tarsi (from Gr., *tarsos*, sole of the foot) of each foot comprise seven irregularly shaped bones—the *os calcis*, or heel-bone; *astragalus* (Gr., *astragalos*, ankle); *cuboid; scaphoid*, or *navicular* bone; and the internal, middle, and external *cuneiform* bones. The *os calcis* is the largest; it projects outward and behind, where it receives the *tendon Achilles* from the muscle of the calf of the leg. It is by this muscle principally that dancers are enabled to raise themselves on the tips of their toes. The bones of the foot, when pulled by this muscle, act as a *lever* of the *second* order. (See Fig. 67.) The *os calcis*, or heel-bone, is very largely developed in the *negro*.

The Metatarsal Bones compose the broad part and front of the arch of each foot, or its lower instep. Each foot comprises five long bones, corresponding with the toes, and having a shaft and two extremities.

The Phalanges of the foot, or the toes, correspond with those of the hand, there being fourteen on each foot.

The Sesamoid Bones are little rounded masses connected with the tendons ; two of them are found under the metatarsal joint of each great toe.

The *arch of the foot* gives great elasticity and grace in walking, running, dancing, and lessens the concussion in leaping and jumping. It is said that during the Crimean war many Russian soldiers belonging to comparatively flat-footed races were disabled by the long marches from the interior.

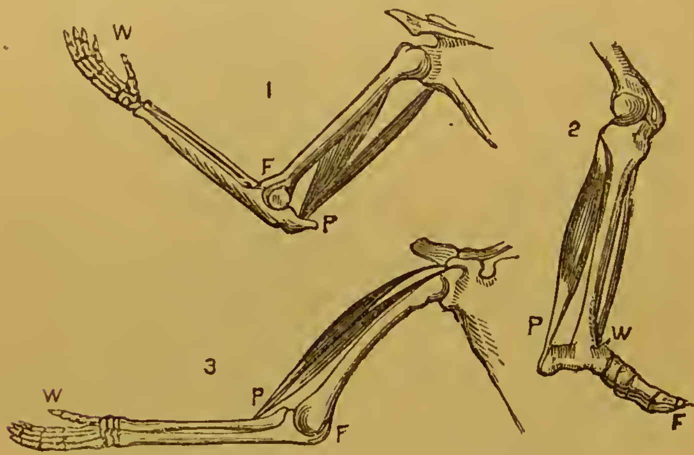


Fig. 67.—Levers in the Human Body.

1. Lever of the *first* order (the *ulna*), moved by the *triceps* muscle at the back of the arm.
2. Lever of the *second* order (the os calcis), moved by the *gastrocnemius* muscle of the calf of the leg.
3. Lever of the *third* order (the radius), moved by the *biceps* muscle in the front of the arm.

W represents the *weight* or resistance ; P, the *power;* and F, the *fulcrum*, or point of support. The kind of lever depends on the relative position of these points.

Points of Ossification.—In early life each bone consists of several distinct parts, each of which might be considered to form a separate bone, the whole ultimately uniting to form a single bone. This separation arises from the commencement of the formation of the bony matter at several points, which are therefore termed *points of ossification.* (See "Cartilage.")

Levers.—Certain bones of the human body are arranged as levers. Thus the *ulna* and the skull form levers of the *first* order; the os calcis forms a lever of the *second* order; and the radius a lever of the *third* order. (See Fig. 67.)

The Articulations or Joints.

The nature of many of the *joints* has already been explained in the description of the osseous system; a more systematic, though brief, description of the structure of the joints or *articulations* is, however, necessary.

A Joint or Articulation is the union of two or more bones, which may be *fixed* or *moveable.* Joints are divided into three classes, which are named according to the *degree of movement* they possess, viz., *synarthrosis*, *amphiarthrosis*, and *diarthrosis.*

Synarthrosis, immoveable joint (from Gr., *syn*, with, and *arthron*, a joint), includes those in which the ends of the bone are in almost immediate contact, are firmly united, and in which there is no intermediate *synovial sac*, as in the *sutures* of the skull. In all cases the periosteum passes in between the ends of the bones.

Amphiarthrosis, mixed joint (from Gr., *amphi*, both, and *arthron*, a joint), includes those in which the ends of the bone are in almost immediate contact, but are united by flat bands of cartilage, or fibro-cartilage, and which therefore allow of limited motion in every direction, as the vertebræ of the spine. This class of joints is intermediate to those of *synarthrosis* and *diarthrosis.*

Diarthrosis, moveable joint (from Gr., *dia*, through, and *arthron*, a joint), is distinguished by its *mobility*, or freedom of movement, as in the shoulder and hip joints.

The ends of the bones which form them are tipped with *true cartilage*, connected by ligaments, and lined with *synovial membrane*. The synovial membrane secretes a viscid, glairy fluid, which lubricates the smooth cartilage-tipped joints, and lessens friction. The structure of this class of joints is the most important and interesting to the student of physiology.

THE MUSCLES AND TENDONS, AND THEIR FUNCTIONS.

The red fleshy solids of the body consist of muscle. Wherever a bone is to be moved, or an organ is to be put into motion, there is muscle. The *muscles* are the *active* agents, as the bones are in general the *passive* agents of motion. The *muscles* constitute the great mass of the body, giving it its general form and proportion.

Number and Arrangement of the Muscles.—The muscles consist of bundles or masses of *muscular fibre* invested in coverings of areolar tissue termed *fasciæ* (from L., *fascis*, a bundle). These bundles are in general large and bulging at their middle or *belly*, but small and tapering at their *extremities*, which usually terminate in *tendinous* cords, which are attached to the ends of the adjacent bones. (See Fig. 67.) Some of the muscles are, however, *circular*, and many others are *flat* or irregularly shaped.

There are about 400 muscles in the human body (Sir Charles Bell gave them as 436), which are in general arranged in pairs. Each pair consists of two *antagonist* muscles, which act in opposition to each other, the one resting while the other is working; the one *bending*, the other *straightening* the limb.

Flexors and Extensors (from L., *flecto*, I bend, and *ex*, out, and *tendo*, I stretch).—Those muscles which bend a limb, as the *biceps* muscle in front of the arm (see 3, Fig. 67), are termed *flexors*. Those muscles which straighten or extend the limbs, as the *triceps* muscle at the back of the arm (see 1, Fig. 67), are termed *extensors*. A *flexor*, with its corresponding *extensor*, constitute a pair of *antagonist* muscles.

The Orbicular and Sphincter Muscles (from L., *orbis*, a circle, and Gr., *sphiggo*, I contract) are circular, oval, or ring-shaped muscles, which surround and by their contraction close certain apertures or orifices, as the *orbicularis oris*, or circular muscle which surrounds and closes the *lips*; the *orbicularis palpebrarum*, which surrounds the *orbit* and eyelids, and by its contraction closes the eyelids; and the *sphincter ani*, which surrounds and closes the terminal aperture of the *rectum*.

Abductor, Adductor, and Levator Muscles (from L., *ab*, from; *ad*, to; and *duco*, I draw).—Those muscles which by their contraction draw one organ or part *from* another are termed *abductors*, as the abductor of the thumb. Those muscles which pull the organ or part inward are termed *adductors*, as the *adductor occuli*, which moves the eyeball inwards. Those muscles which raise or lift up the parts to which they are attached are termed *levator* muscles, as the *levatores costarum*. (See Fig. 31.)

Names of the Muscles.—In addition to the classes of muscles already given, muscles are named—(1) according to their *shape*, as the *deltoid*, *denticulated*, rectus, *rhomboidal*, square, triangular, and *oblique* muscles; (2) according to the parts of the body to which they are attached, as the *abdominal*, *brachial*, *cervical*, *crural*, *dorsal*, *facial*, *pectoral*, *pelvic*, and *thoracic* muscles; (3) from their divisions, as the *biceps* and *triceps* muscles.

Origin and Insertion.—The end of the muscle which is attached to the immoveable bone is termed its *origin*, and that extremity which is attached to the moveable bone its *insertion*; the intermediate part of the muscle, when full and thick, is termed its *belly*. (See Fig. 67.)

Voluntary and Involuntary Muscles (from L., *volo*, I will, and *in*, not).—The muscles of prehension and locomotion, &c., act according to and under the direction of the *will*, and are therefore

termed *voluntary* muscles. Those organs, the movements of which are essential to life, are supplied with muscles which act independently of the will, and are hence termed *involuntary* muscles. The principal *involuntary* muscles are the *heart* and the muscles of *respiration* and *digestion*. The *involuntary* muscles, being independent of the will, act at all times, *sleeping* or *waking*. Were they dependent on the will, their action would immediately cease on our going to sleep, in which case *circulation* and *respiration* would both cease, and death would follow as a necessary consequence.

Muscular Contraction.—Muscles possess the property of *active contractility*, and *tonicity*, or passive contractility. When the muscles contract they become harder and about one-third shorter, but they do not lessen in real bulk. Portions only of a muscle contract at one time, those fibres which are at rest assuming a zig-zag direction. When a muscle is kept long in action its various fibrils alternately rest and contract. (See "Muscular Tissue.")

The Tendons are the white, glistening, tough, *inelastic*, flexible cords by which the ends of the muscles are attached to the bones. They consist of white fibrous tissue, and are very sparingly supplied with nerves and bloodvessels. They are well and familiarly shown in the claw of a fowl.

Bloodvessels, Nerves, and Lymphatics.—The muscles are well supplied with bloodvessels, nerves, and lymphatics. It is said that the blood which leaves a muscle in action is of a dark colour, while that which leaves a muscle in a state of rest is of a bright scarlet colour, like arterial blood.

ORGANS OF THE VOICE, AND THEIR FUNCTIONS.

Voice and Speech, or the utterance of words, though frequently confounded with each other, are

in reality distinct phenomena. *Voice* is the open sound produced by the distended vocal cords when put into sufficiently rapid *vibration* by the passage of the air expelled through the *trachea*, as when we produce a continuous O, or other *vowel* sound. If an incision be made in the *trachea* below the larynx, or voice-box, and the expired air be expelled through it, voice is not produced.

Ordinary *speech* consists of the *voice* chiselled, shaped, or sculptured into words by means of the *tongue*, *teeth*, *palate*, *cheeks*, *lips*, *nose*, &c. But speech is quite possible without voice, as in the case of *whispering*. Voice is only possible when the *glottis*, or breathing chink, is *open;* hence arises the impropriety and even danger of speaking and laughing during the processes of eating and drinking.

The *acoustic* principle on which the organ of the voice is constructed resembles that of a *reed* instrument, such as the hautboy or flageolet, which combines the principles of the vibrating tongue and the tube combined. This will be better understood after referring to the simple instrument represented by Fig. 68. On blowing through the tube, the free edges of the membranes will be put into rapid vibration, and sound waves, somewhat resembling some of the tones of the human voice, will be emitted.

Fig. 68.

The Larynx (from Gr., *larugx*, the orifice of the windpipe), or organ of the voice, is a box-like structure, somewhat resembling an irregular inverted cone, situated at the top of the *trachea*, or windpipe, immediately in front of the œsophagus, and under the root of the tongue. It forms the well-known

prominence in the upper part of the throat known as *Adam's apple*, or the *pomum Adami;* this prominence is much greater in men than in women. The

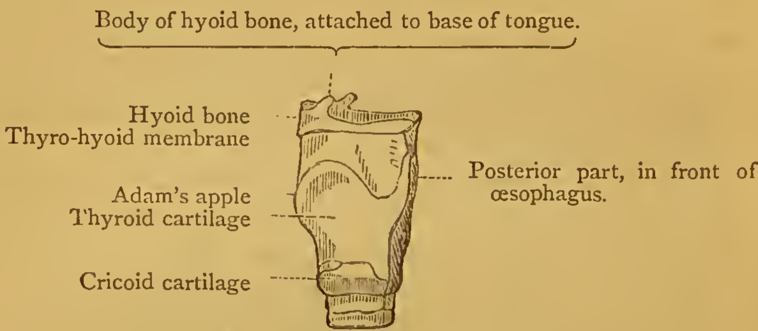
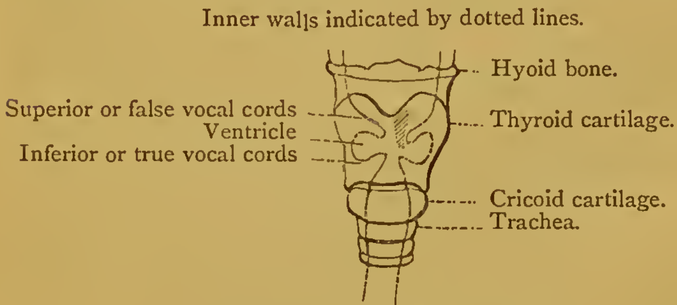


Fig. 69.—Side of the Larynx.

larynx consists of nine cartilages, united together by ligaments; these cartilages are moved and regulated by eight intrinsic muscles. Two moveable elastic membranous folds, termed the vocal cords, extend from the front to the back of the larynx, or voice-box.



Inner walls indicated by dotted lines.

Fig. 70.—Front View of Larynx.

The whole is lined by delicate mucous membrane, studded with mucous glands, by the secretions of which its surface is kept moist and flexible; it is

also well supplied with bloodvessels, nerves, and lymphatics. In addition to the membranous folds, the vocal cords previously mentioned, there are the upper and less perfectly developed folds, termed the false vocal cords.

Cartilages of the Larynx. — Besides the *epiglottis*, which may be considered a sort of adjunct, the *larynx* comprises four principal cartilages, which constitute its framework, viz., the thyroid cartilage, the cricoid cartilages, and the two arytenoid cartilages. The remaining cartilages are the two cornicula laryngis, and the two cuneiform cartilages.

The Thyroid Cartilage (from Gr., *thureos*, a shield, and *eidos*, shape) is the largest and most important cartilage in the larynx. It consists of two wings, or *alæ*, bent at an acute angle, which form the Adam's apple in front of the throat previously referred to. It is open behind. (See Fig. 71.) Each lateral

Fig. 71.—THYROID CARTILAGE (front).

1. Adam's apple.
2. Right wing or *ala*.
3. Superior cornu or horn.
4. Inferior cornu.

half or wing has an upper and a lower horn, respectively termed the *superior* and *inferior cornu*, projecting from it. The upper margin of the thyroid cartilage, which is curved like the letter ∽ placed on its side, is connected by a broad membrane with the *hyoid* or tongue bone. Its lower front, or middle border, which does not touch the *cricoid* cartilage, is connected with it by the *thyro-cricoid* membrane; the inferior horns are attached to the outside of the *cricoid* cartilage, on which it performs a riding or see-saw motion, through the agency of the *thyro-cricoid* muscles,

by which movement the *tension* of the vocal cords, and therefore the *pitch* of the voice, is determined.

The Cricoid Cartilage (from Gr., *krikos*, a ring) somewhat resembles a signet ring, being much broader behind than in front. (See Fig. 72.) It forms a complete ring, being the only entire

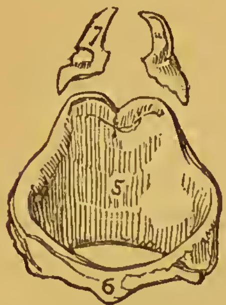


Fig. 72.—Front View of Cricoid and Arytenoid Cartilages.

5. Interior of back of cricoid cartilage.
6. Front of cricoid cartilage.
7. Arytenoid cartilages.

ring in the trachea. Its lower edge is connected by membrane with the upper ring of the trachea, on which it rests. Its upper middle border is connected with the thyroid cartilage by means of the crico-thyroid membrane (see Fig. 73) ; at its sides it is overlapped by the inferior horns of the thyroid cartilage, which are attached to and play upon little facets on the cricoid cartilage, producing the riding motion by which the *vocal cords* are adjusted as previously described.

The Arytenoid Cartilages (from Gr., *arutaina*, a pitcher, and *eidos*, form) are two small pyramidal bodies, so called from the resemblance they are supposed to bear, when approximated, to the mouth of a pitcher. (See Fig. 72.) They are attached by their bases to the upper edge of the back of the cricoid cartilage, so as to admit of a backward and forward, an upward and downward, and a lateral movement ; also a motion on an imaginary vertical axis passing from above, by which the corners are turned inwards or outwards, like the motion of an ordinary bell-crank. In consequence of the great mobility of these parts, and of the exquisite perfection of the muscular arrangements connected with them, it is calculated that 900 changes per minute can be effected in the moveable organs of speech, and that this series of rapid changes may be sustained for hours, as in the process of reading, speaking, &c.

The Epiglottis (from Gr., *epi*, upon, and *glotta*, the tongue) is a yellowish leaf-shaped, fibro-cartilaginous valve. Its apex, which is pointed downwards, is attached to the upper part of the

inner angle of the thyroid cartilage; it is also attached to the hyoid bone. It lies immediately behind the root of the tongue, and during respiration and when talking inclines backwards towards the tongue. But during the process of swallowing the

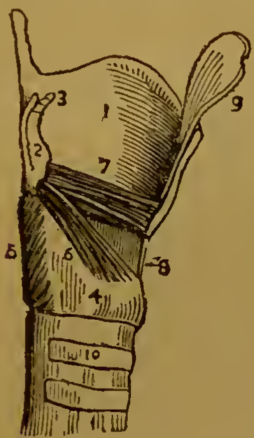


Fig. 73.—Interior of Larynx.

1. Inside of left thyroid cartilage.
2, 3. Arytenoid cartilage.
4. Cricoid ,,
5. Posterior crico-arytenoid muscle.
6. Lateral ,, ,, ,,
7. Thyro-arytenoid muscle.
8. Crico-thyroid membrane.
9. Epiglottis.
10. Ring of trachea.

trachea is drawn *forward* under the root of the tongue; the *epiglottis* is bent down upon the superior opening of the larynx, which it closes after the manner of a trap-door. Its surface is lined with mucous membrane, which is studded with mucous glands.

The Upper or False Vocal Cords consist of two *folds* of *mucous membrane* at a short distance *above* the *true* vocal cords.

The Ventricle of the Larynx is the space between the *true* and *false* vocal cords.

The True Vocal Cords, or the inferior thyro-arytenoid ligaments, consist of two thin, broad, elastic, membranous folds, formed of *yellow elastic fibrous* tissue, and lined with *mucous* membrane. These folds constitute the *immediate* organs of the voice. One of these cords or folds is attached to the base of each of the *arytenoid* cartilages, and passes from it across the *larynx* to a recess in the *thyroid* cartilage on the opposite side, where it meets the end of the remaining cord, both cords being inserted at the same point. A narrow V-shaped aperture, termed the glottis, is thus formed; the vocal cords, together with the folds of mucous

membrane by which they are invested, close up the whole aperture of the larynx, excepting the V-shaped chink described. All the air which passes to or from the lungs therefore passes through this chink. When the vocal ligaments are loose, and the aperture is V-shaped, we respire noiselessly; but when, by the action of the muscles, the cords are brought into a state of tension, and their edges are approximated and made parallel to each other, the act of breathing puts them into a state of rapid vibration, and *sound waves*, which constitute *voice*, are produced. The pitch of the voice depends upon the length and tension of the vocal cords.

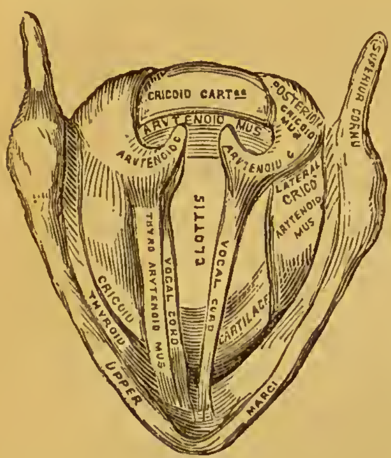


Fig. 74.—Bird's Eye View of Larynx.

The Nerves of the Larynx consist of two branches of the *pneumogastric* nerve,—1. The *superior laryngeal*, or sensory nerve, which is distributed to the mucous membrane; it serves, among other purposes, to test the purity of the air respired. 2. The *inferior* or *recurrent laryngeal* nerve, which supplies the power of motion to all the laryngeal muscles except the *crico-thyroid* muscles, which receive branches from the *spinal accessory*. The larynx is also supplied with nerves from the sympathetic system.

Function of Larynx.—The larynx is the organ of the voice. Its structure and action, as has been before shown, resemble those of the class of wind musical instruments known as reed instruments. An artificial larynx has been constructed by Mr. Willis, of wooden tubes and sheet India-rubber vibrating mem-

branes, on this principle, the tones evolved from which closely resembled some of those in the human voice. More recently an improved apparatus has been constructed, which is capable of producing certain sentences intelligibly. The human voice is caused by the vibration of the vocal cords; its pitch depends on the tension and consequent rapidity of the vibration of these cords. This has been proved by attaching a scale-pan to the *thyroid* cartilage of a dead human larynx, and blowing through the lower end of the trachea either with the mouth or with a pair of bellows; the sound of the human voice is produced, the pitch of which is heightened by placing additional weights in the scale-pan, which by drawing down the thyroid cartilage with greater force, stretch the vocal cords more tightly. If the elastic power of the cords be injured by cold or disease, or if they be cut, hoarseness or loss of the voice (*aphonia*) will follow. If the inferior laryngeal nerves be cut or paralyzed, the laryngeal muscles lose their power of contraction, and thereby of tightening and governing the vocal cords; this result being followed by loss of voice.

Singing.—In singing the vocal cords are made to vibrate isochronously—that is, in equal times. Each note requires a definite number of vibrations per second for its production.

The Loudness of the Voice depends principally on the volume of air and the rapidity and force with which it is expelled by the muscles of the chest. It also depends partly upon the resonance of the nasal and cranial cavities, and upon the shape and size of the buccal cavity and oral aperture.

The Timbre, or peculiar quality of the voice, as distinct from mere tone, depends probably upon the surfaces, shape, and the general quality of the material of the vocal organs and adjacent cavities.

Stammering, or stuttering, arises from the want of power to continue or *co-ordinate* the various muscular motions necessary to

speech. The vocal organs are not under the complete control of the will. Thus, in pronouncing potato, the will has not the power to co-ordinate or combine the motion of the lips, the teeth, the tongue, and the glottis; the lips continuing to repeat the first, the *explosive* portion of the word, while the *glottis* remains *spasmodically* closed, and for some time refuses to produce the remaining portion of the word.

THE NERVOUS SYSTEM AND ITS FUNCTIONS.

The Nervous System comprises the *brain*, *spinal cord*, *cerebro-spinal nerves*, and a distinct *system of nerves* and *ganglia*, termed the *organic*, *sympathetic*, or *ganglionic* nerves. (See Fig. 75.) It forms the highest structure in the animal organism; it does not exist, even in a *rudimentary* form, in the bodies of the lowest grade of animals. It is found in its highest state of development in the body of man, being most perfectly developed in the most cultivated and endowed of the human race. True education consists mainly in developing and conserving the *vital* force of the system, and so directing it as to lead to the development of the *highest* possible type of the *nervous system*, care being always taken that no other part of the body *is robbed* of the *vital* force required for its own particular *development* and *health.*

The *brain* is the organ of the *mind.* Its *functions* are sensational, ideational, intellectual, emotional, and volitional; that is, the *mental* operations of Sensation, Perception, Memory, the Passions, Sentiments, Feelings, and the Will, are performed *by* or through the *agency* of the *brain*, and depend for their perfection and power on the *quality* and *development* of the various structures which, in the aggregate, form the *brain.* The various parts of the brain are *differently* constituted and perform *different* functions. But many

parts of the nervous system, apparently *similar* in *structure*, perform *dissimilar functions;* thus no difference can be detected in the *structure* or *chemical com-*

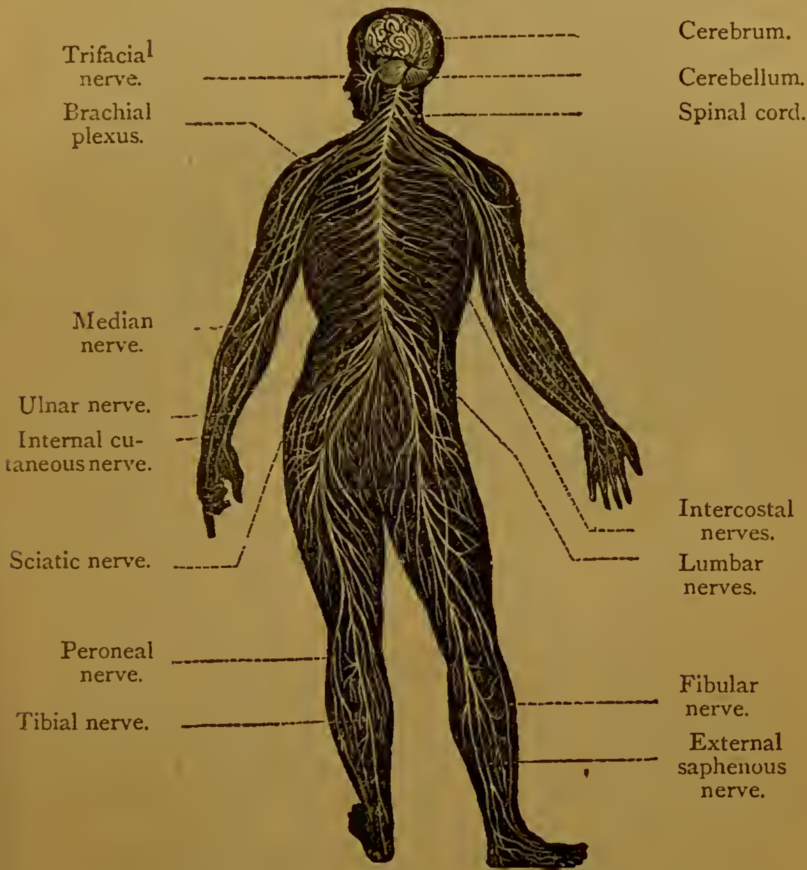


Fig. 75.—PLAN OF THE NERVOUS SYSTEM OF MAN.

position of the nerves of *sensation* and *motion*, yet their *functions* are entirely different. The one set of nerves (*sensory* or *afferent*) convey impressions received from without *to* the *brain*, in which they give rise to *sensation;* the latter set (the *motor* or *efferent* nerves) convey the effect of the will *from* the brain *to* the part, so as to produce motion in that part to which the *nervous influence* is *conveyed.*

The *functions* of the various parts of the nervous system cannot be ascertained with any degree of certainty by *vivisection.* The *functions* of many organs of the body may, on the contrary, be readily determined by dissecting them from the living body and observing what *function* ceases to be performed, such function being in all probability that performed by the *excised* organ; but the various parts of the nervous system are so intimately related, and the *sympathy* between them is so perfect, that the *injury* of any one important part of the *brain* or *nerves* disturbs the *functions* of so many others, that it becomes impossible to say which of the functions so disturbed or arrested was performed by the particular *nerve* or section of the *brain* injured. Thus a *shock* received at any of the *nervous centres* may *paralyze* the organs of digestion, respiration, or circulation, and produce *death.* A moistened leaf of tobacco placed on the skin of the upper arm will produce sickness though none of it pass into the *stomach.* A cut on the finger, an offensive smell, a horrible sight, and many other influences having no immediate relation to the *stomach* may, through the perfect sympathy subsisting between the various portions of the *nervous system*, produce effects in various parts of the body remote from those directly affected.

Parts of the Brain.—The principal parts of the brain are the *cerebrum*, or brain proper; the *cerebellum*, or lesser brain; the *corpus callosum*, or commissure which unites the two hemispheres of the cerebrum; the *pons Varolii*, or commissure which unites the two lobes of the cerebellum; and the *medulla oblongata.* There are also certain *ganglia* situated at the *base* of the brain, viz., the *corpora striata*, the *optici thalami*, the *corpora quadrigemina*, and the *pineal gland.* (See Fig. 76.) These *ganglia*

are situated immediately under the *corpus callosum.* The *olfactory lobes*, two small oblong masses of *grey* matter which give off the true nerves of *smell*, are

Fig. 76.—PLAN OF VERTICAL SECTION OF THE BRAIN AND THE COLUMNS OF THE MEDULLA OBLONGATA.

Showing the course of the nervous *fibres* from the *spinal cord* to the various parts of the *brain.*

A. The cerebellum. B B. The cerebrum.
C C. The crus cerebri, or right peduncle of the cerebrum, the fibres of which pass through the *corpus striatum* and *optic thalamus.*

situated underneath the front lobes of the cerebrum.

From the mode in which the lower surfaces of the brain fold in upon each other, five cavities or spaces, termed the *ventricles* of the brain, are formed. The opposite sides of the *ventricles* touch each other in

their interior; they are lined with the arachnoid membrane, and their surfaces are moistened by a thin serous fluid. Among other uses they subserve, they permit of the passage of bloodvessels to and from the interior of the brain.

The brain is invested by three membranes—1, the *pia mater* or *inner* membrane, which is immediately in contact with it; 2, a *middle* membrane, the *arachnoid* membrane; and 3, an *outer* membrane, termed the *dura mater*, which lines the interior of the skull, and forms certain canals or venous *sinuses* for the circulation of the blood in the cranial cavity.

The human brain weighs about 50 ounces; that of the horse about 19 ounces; the elephant, 130 to 160 ounces; and that of the whale about 80 ounces.

The Cerebrum, or Brain Proper, consists of two large, similar, and equal ovoid masses, termed hemispheres, separated by a long, deep *median* groove, termed the great *longitudinal fissure*, which passes from the *front* to the *back* of the brain. A crescent-shaped fold of the *dura mater*, termed the *falcx*, dips into the bottom of this *fissure*, forming a *septum*, which helps still further to separate the *hemispheres* and to retain them in their respective situations. Each *hemisphere* is divided by anatomists into three *lobes*, viz., the *anterior* lobe, which is bounded on the under surface of the brain by the *fissure of Sylvius;* the *posterior* lobe, which covers the *cerebellum;* and a *middle* lobe, which is situated between the *fissure of Sylvius* and the *lobe* overlying the *cerebellum.* The surface of the *cerebrum* is also broken by a number of irregular *fissures* or *sulci* of various depths. The irregular folds of brain bounded by these fissures are termed *convolutions.* The peculiar arrangement of these *sulci* and *convolutions*, or *gyri*, give the brain a folded up appearance, as shown in the diagram (see

Figs. 75 and 77), their object being, in all probability,

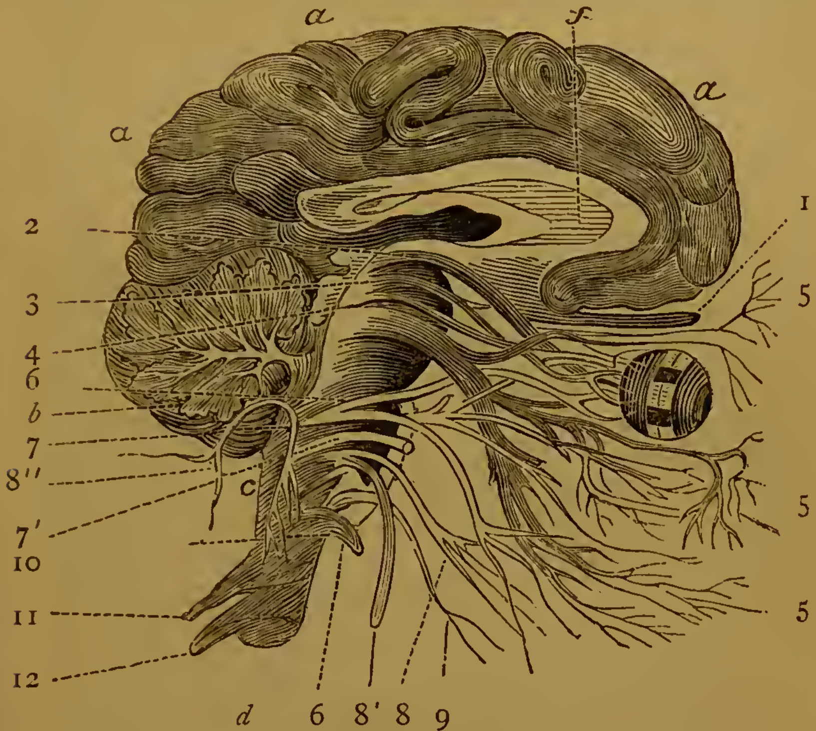


Fig. 77.—Vertical Section of the Human Brain, with Cranial Nerves.

Showing the left hemispheres of cerebrum and cerebellum, separated by the great longitudinal fissure.

a a a. Cerebrum.
b. Cerebellum.
c. Medulla oblongata.
d. Spinal cord.
f. Corpus callosum.
1. Olfactory lobe.
2. Optic nerve.
3. Motor oculi.
4. Trochlear nerve.
5. Trifacial nerve.
6. Abducens nerve.
7. Portio dura of 7th nerve.
7'. Auditory nerve.
8. Glossopharyngeal nerve.
8'. Par vagum.
8''. Spinal accessory nerve.
9. Hypoglossal nerve.
10, 11, 12. Spinal nerves.

simply to *increase* its surface. The two *hemispheres* are united below the *longitudinal fissure* by a *transverse commissure* termed the *corpus callosum* (from L., *callus*,

hardness), which consists of a collection of white nerve fibres passing *transversely* from one hemisphere to the other. (See *f*, Fig. 77.) At the *base* of the cerebral hemispheres, *below* the *corpus callosum*, are four narrow cavities or chambers termed the *ventricles* of the brain.

The *surface* (cortical layer) of the cerebral hemispheres, which is of a pinkish grey colour, is composed of *vesicular* nerve substance. The mental endowments, including under that term the *intellect*, the *passions*, *emotions*, *affections*, and *volitions*, in all probability depend upon the *extent* of surface, the thickness, and the *quality* of this *vesicular* nerve substance. The *medullary* or interior portion of the brain consists principally of *white tubular nerve fibre*, the greater portion of which diverges and *radiates* to the surface. Numerous other *fibres* pass *transversely* and *longitudinally*, so that all parts of the *brain* are brought into *connection* with each other and with the *spinal cord*, and through it probably with all parts of the body.

Functions of the Cerebrum.—The cerebrum is the seat of the Intellect, Emotions, and the Will. When *very* small, the human being is idiotic; when removed from the lower animals, they lose their *memory* and power of *volition*. When it becomes inflamed or softened, *mania* or *idiotcy* sets in; and when it is acted upon by poisons or *intoxicating* agents, the intelligence and the reasoning powers are affected.

The Sensorium, or seat of sensation (See page 14), is not accurately determined, but there is every reason to believe it is situated at the base of the brain, near the *medulla oblongata*. If the brain of a pigeon or other small animal is sliced away, it shows no signs of sensation until the knife reaches the medulla oblongata or the adjacent ganglia, when it manifests great pain.

The Cerebellum, or Lesser Brain, is situated at the base of the back of the *cranium*, under the *posterior* lobe of the *cerebrum;* it is contained in a distinct compartment, being separated from the *cerebrum* by a fold of the *dura mater*, termed the *tentorium.* The *tentorium* forms a *roof* for the *cerebellum*, and a *floor* for the support of the *posterior* lobe of the cerebrum. The cat, tiger, and other animals which spring on to their prey are furnished with *bony* tentoriums. The *cerebellum* consists of two larger symmetrical, lateral *hemispheres*, and a smaller *median lobe* or mass. Each *hemisphere* is formed of a series of about ten parallel *laminæ.* Each *lamina* consists of a layer of *white* nerve *fibre*, or *medullary* substance, covered with *grey* or *vesicular* nerve substance. The peculiar arrangement of *grey* and *white* or of *cortical* and *medullary* nerve substance of the *cerebellum* gives rise, when cut perpendicularly, to a peculiar *foliated* or branched appearance, termed the *arbor vitæ*, or tree of life, of the *cerebellum.*

The Crus Cerebelli (from L., *crus*, leg), or central stem of the *cerebellum*, consists of three *peduncles* or stalks, by which the *cerebellum* is connected with the *cerebrum* and the *medulla oblongata*, and by which its two *hemispheres* are connected with each other. (See Fig. 76.) The *ascending* peduncles *connect* it through the *corpora quadrigemina.* The *descending* peduncles connect it with the *posterior* columns of the *medulla oblongata* ; and the *middle* peduncles connect its opposite *hemispheres*, and blend into the *pons Varolii.*

Size and Weight of Cerebellum.—All the vertebrate animals, with one or two exceptions, have a cerebellum. The *median* lobe only is found in fishes and reptiles. The invertebrata do *not* possess a cerebellum. In man it forms about one-tenth the

weight of the entire *brain*, and is about one-eighth the weight of the *cerebrum*.

The Functions of the Cerebellum are by no means satisfactorily determined. It is supposed to *regulate* or co-ordinate voluntary *muscular* action; that is, to *combine* and *harmonize* the *separate* actions of the various muscles of the body, so as to produce one *resultant* movement.

Animals in whom the *cerebellum* is diseased or *injured* lose the power of *regulating* their *muscular* movements.

It does not seem to possess any power of *sensation*, injury to it apparently producing no pain. When the cerebellum of a bird or other animal is partially *removed*, or a *cut* made into its substance, it loses all power of *regulating* its *movements*, and will walk backwards or sideways, or rotate on one leg, or roll over, or perform almost any kind of abnormal movement, showing that probably, in some way or other, the cerebellum presides over or governs the voluntary muscular movements. The animals appear to retain their consciousness, memory, and power of volition during the experiment. When the *last* portions of the *cerebellum* have been removed, the animal loses all power of standing, walking, springing, or flying. Man, in whom the *cerebellum* is more *largely* developed than it is in any of the lower animals, possesses the power of performing the most varied, complex, and delicate movements. In some forms of insanity the patient incessantly occupies himself in turning round and round; this probably results from disease of this organ. Phrenologists assign this organ as the seat of sexual love, in support of which they produce much evidence.

The Convolutions, Folds, or Gyri are ap-

parently devices for increasing the surface and therefore the quantity of *vesicular* nerve substance of the *brain.*

The brains of the lower animals are smooth and *non-convoluted.* The brains of animals of a higher grade are convoluted, but the *convolutions* are comparatively *few* and *small.* They are most *numerous* and *deepest* in man, their depth and extent apparently increasing with his *mental* power. The brains of the lowest races of mankind are said to be smoother, that is, have fewer *convolutions*, and these less deep, than those of the higher civilized races; so that the brains of the lower races bear a closer resemblance to the brains of the common animals than those of the higher or more civilized races. The *convolutions* are said to be less deep in *females* than in males, and to decrease in advanced old age; they thus seem to bear a *proportion* to the *mental* powers of the individual. The average surface of the brain is said to be about 670 square inches.

The Sulci, or furrows in the surface of the brain, which bound the convolutions, agree with them in depth. They are lined by the *pia mater*, which dips down to their floor. They contain a fluid termed the cerebro-spinal fluid, which is retained between the *pia mater* and the *arachnoid* membrane; the latter membrane does not enter the *sulci.* These spaces are sometimes termed the *sub-arachnoid* spaces.

The Cerebro-spinal Fluid is a very limpid, albuminous liquid, having a saltish taste, a sickly odour, and an *alkaline* reaction. It is found in the *sub-arachnoid* spaces of the *cranium* and the *vertebral canal.* (See Fig. 79.)

Its *function* is to protect the delicate *membranes* of the *brain* and *nerves* from external shock, and to equalize the *pressure* on the brain; it varies in quantity *inversely* with that of *blood* in the brain. The usual quantity in the skull is about 2 ounces, but this may be increased to 10 or even 12 ounces after heavy bleeding or from other causes.

The Pia Mater is a very delicate *fibro-vascular* membrane, which immediately invests the *brain* and *spinal cord*, following their contour, *dipping* into the *sulci* or *fissures*, and lining the

ventricles of the brain. It consists of delicate *white fibrous tissue* and a network of *bloodvessels.* Its principal functions are—1, to allow the bloodvessels which enter the skull to break up into innumerable minute branches before entering the *substance* of the *brain;* 2, to supply the *cerebro-spinal* fluid. It forms a close-fitting *sheath* to the *spinal cord,* and gives off a *serrated* membranous process, termed the *denticulate ligament,* also a *filamentous* process, termed the *filum terminale,* by which the *spinal cord* is safely retained in its proper position.

Tabular View of the Cranial Nerves and their Functions.

Arise from the brain or pons Varolii.	1st. Olfactory nerve,	distributed	to the *lining* membrane of the nose, is the special nerve of *smell.*
	2nd. Optic nerve,	”	to the eyeball, the special nerve of *sight.*
	3rd. Motor oculi,	”	to the *levator palpebræ* of the upper eyelid, and superior, inferior, and internal straight, and the inferior oblique muscles of the eyeball —a *motor* nerve.
	4th. Trochlear nerve,	”	to the *trochlear,* or pulley muscle of the eyeball and fibrils; to the *lachrymal* gland.
	5th. Trifacial nerve. Ophthalmic branch,	”	to the orbit, eyeball, lachrymal gland, cavity of the nose, palate, gums, and teeth of upper jaw—a *sensory* nerve.
	Superior maxillary branch,	”	
	Inferior maxillary branch,	”	a *motor* nerve to the muscles of mastication —*sensory* to the tongue —the *gustatory* a special nerve of *taste.*
	6th. Abducens nerve,	”	to the external straight muscle of the eye, which pulls the eye outward — a *motor* nerve.

Arise from the medulla oblongata.	7th.	Portia dura,	distributed	to muscles of face and of hyoid bone, and to sub-maxillary and sub-lingual glands—a *motor* nerve.
		Portia mollis,	,,	to the deep parts of the ear, the special nerve of hearing (auditory).
	8th.	Glossopharyngeal nerve,	,,	to tongue, pharynx, soft palate, and tonsil —a *sensory* nerve.
		Pneumogastric nerve, or par vagum,	,,	to muscles and mucous membrane of pharynx, larynx, trachea, bronchi, lungs, heart, and stomach—a mixed *sensory* and *motor* nerve.
		Spinal accessory nerve,	,,	to the muscles of the neck and back; forms the external respiratory nerve of motion.
	9th.	Hypoglossal nerve (or lingual)	,,	to the muscles of the tongue—a *motor* nerve.

It will be seen by the above table that the cranial nerves are of three kinds—*sensory*, *motor*, and *mixed.*

The Arachnoid Membrane (from Gr., *arachnes*, a spider, and *eidos*, appearance) is a closed *serous* sac which lines the brain and spinal cord. Its inner or *visceral* layer is attached loosely to the *pia mater*, and its outer or parietal layer is firmly attached to the inside of the *dura mater* which lines the interior of the skull. It is attached, but *loosely*, to the *dura mater* which lines the *spinal cord.* The space enclosed within the sac is called the *arachnoid* cavity; it is moistened by *serous* fluid (the cerebro-spinal fluid).

The Cranial Nerves consist of *nine* pairs of nerves,—so called because they pass out of the *foraminæ* at the *base* of the cranium,—which are distributed symmetrically on the two sides of the body. (See Fig. 77.) They are named according to the order in which they pass out of the skull, and the

functions they perform, or the parts to which they are distributed. (See Tabular view, page 302.)

The Medulla Oblongata is the *cranial* prolongation of the *spinal cord*, or that portion of it which is contained within the cavity of the *skull*. Its relation to the *spinal cord* has been compared to that of the *capital* of a column to its *shaft*. (See Fig. 78.) Its

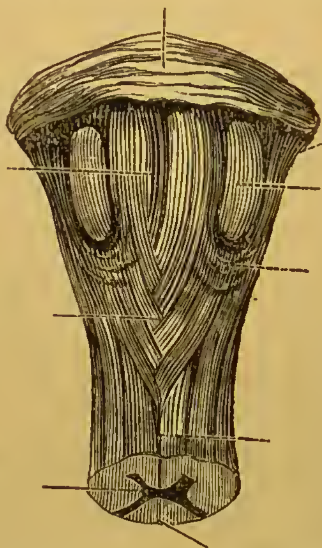


Fig. 78.—Anterior Surface of the Medulla Oblongata.

functions are similar to those of the *spinal cord*, but they are more *essential* to life. It forms the connection between the *cerebrum*, *cerebellum*, *mesophale*, and the rest of the nervous system, and thus brings the *mind* into *relation* with the whole of the *body*. If it is severed from the brain by section at its *upper* end, the body still *lives*, but loses all power of *sensation*

and *voluntary* muscular movement. If it be detached from the *spinal cord* by section at its *lower* end, the processes of *respiration* and *circulation* are arrested, and *life* immediately ceases.

The *medulla oblongata*, viewed *transversely*, is somewhat *oval* shaped; viewed *perpendicularly*, it is of a *pyramidal* shape, being larger at the top, where it joins the *brain*, than at its base, where it is united to the *spinal cord*. It is divided into two lateral similarly shaped halves by an *anterior* and a *posterior* fissure. The anterior fissure is wider and less deep than that of the spinal cord, from which it is separated by the *decussating* fibres.

Each *lateral* half of the *medulla oblongata* is divided into four sections or bodies by certain well-marked *grooves* in its surface:—1, the *anterior pyramid*, by which it is joined to the cerebrum, the seat of intellect and volition; 2, the *olivary body*, an oval-shaped ganglion; 3, the *restiform* (rope-like, from its twisted appearance) *bodies*, by which it is united to the cerebellum, the seat of the power of muscular coordination; 4, the *posterior pyramid*, which is a part of the restiform body, marked off from it by a superficial groove. (See Figs. 76 and 78.)

The *medulla oblongata* consists of *grey* and *white* nerve substance, the white being principally on the exterior, forming the *cortical* layer. The *grey* matter is not, however, confined exclusively to its interior, as in the case of the *spinal cord*, but is very generally and somewhat confusedly distributed throughout its substance. On careful examination after section its fibres are seen to *decussate* (cross from one side to the other) very freely.

The Decussation (from L., *decusso*, I cut across), or crossing of the *anterior* columns (see Fig. 78), has been suggested as the natural boundary separating

the *medulla oblongata* from the *spinal cord.* Three to five bundles of fibres, termed *decussating* fibres, from the end of the *anterior* pyramids of the spinal column, cross the *anterior median fissure*, dividing the upper part of the fissure from the lower, and proceed to the opposite hemispheres of the brain. This explains why injury or disease on one side of the brain, as in the case of railway accidents, produces *paralysis* in the *opposite* limb or side of the body; whereas if the nerves be injured or diseased *below* the point of *decussation*, the *same* side of the body only may be affected. (See "Course of Sensory Impressions" and "Motor Impulses.") The *arciform fibres* also unite the *cerebellar* columns with the *anterior* columns of the spinal cord.

THE SPINAL CORD AND ITS FUNCTIONS.

Appearance, Size, and Situation.—The spinal cord is the flattened cylindrical body which is contained in the *vertebral canal.* It is connected with the brain by the *medulla oblongata*, and with the various parts of the body by the thirty-one *pairs* of nerves it sends off *laterally.* It reaches from the *foramen magnum* of the skull to the *first* lumbar vertebra; is about 16 inches long, and weighs (when its nerves and membranes are detached) about $1\frac{1}{2}$ ounces. It has a cervical and lumbar *enlargement*, from which it gives off the nerves which pass respectively to the upper and lower extremities. At its termination it gives off the leash of nerves termed (from its appearance) the *cauda equina*, or horse's tail. The *central* filament of the cauda equina, designated the *filum terminale*, consists of *fibrous* tissue; it passes down the centre of the spinal canal, and helps to

retain it in its place; but it is retained in its position chiefly by a *serrated* ligament, which is given off on each side of the cord from the *pia mater*, and which extends from the skull to the *filum terminale.* Each side of this ligament has a smooth interior border, attached to the *pia mater* of the cord, and an outer *serrated* border, which is attached by about twenty tooth-like processes to the sides of the *dura mater;* this membrane has therefore been termed the *denticulate* ligament, or *ligamentum denticulatum.* It separates the roots of the *posterior* and *anterior* spinal nerves. (See Fig. 79.)

The spinal cord is divided into two lateral halves by two *fissures*—the *anterior median* fissure and the *posterior median* fissure, the latter being narrower but deeper than the former. Each *lateral* half of the cord is again divided by the line of anterior and posterior spinal nerves into three *columns*, viz., an *anterior*, *lateral*, and *posterior* column.

Structure of the Spinal Cord.—If a *transverse* section of the spinal cord be examined, it will be seen to consist of *white* and *grey* nerve matter (see Fig. 79); the relative position of these substances being reversed in the cord as compared with the brain, the *white* or tubular nerve fibre, which forms the greater part of the cord, occupying the exterior, and the *grey* or *vesicular* nerve substance the interior. The grey matter is collected in the form of two *crescentic* or half-moon shaped masses, the *concavities* of which are turned outwards, their *convexities* being turned towards and connected with each other by a *transverse* commissure of grey matter. (See Figs. 78 and 79.)

Each of these masses has an anterior and a posterior *cornu* or horn. The *anterior* cornua, which are round and thick, and do not reach the surface, give off the *roots* of the *anterior* or *motor* nerves; and the *posterior* cornua, which reach the surface by irregular or stellate processes, give off the *posterior* or *sensory* roots. The portions of the cord bounded by these nerves constitute the *lateral* columns. The anterior and posterior roots

which emerge from the cord *join* as they pass through the *intervertebral foraminæ*. (See "Vertebral Column.") The centre of the grey commissure of the spinal cord is perforated by a minute canal about 1-100th of an inch in diameter, which is continuous with the 4th ventricle.

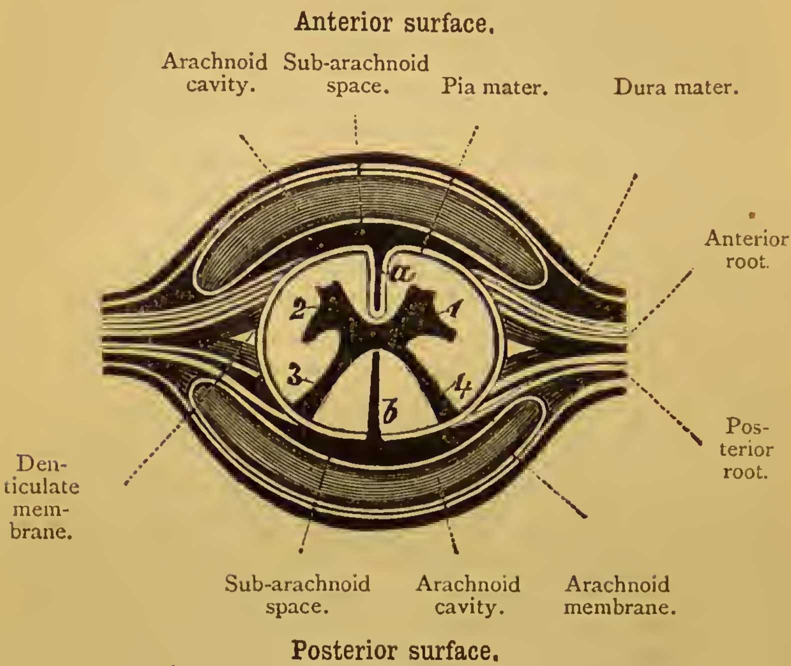


Fig. 79.—Plan of Transverse Section of Spinal Cord and its Membranes.

Showing—*a*. Anterior median fissure.
b. Posterior ,,
1, 2. Anterior cornua.
3, 4. Posterior ,,

The white fibrous portion of the spinal cord comprises *transverse*, *oblique*, and *longitudinal* nerve fibres, a portion only of which passes to the brain, a considerable portion of the cord consisting of commissural fibres, which unite the nerves which enter the different parts of the cord.

Functions of the Spinal Cord.—The following are probably the chief functions of the spinal cord:—1, it conducts *sensory impressions* to the brain; 2, it conveys *motor* impulses *from* the brain to the voluntary muscles; 3, it acts as a *centre of motion* altogether independently of sensation and volition, and therefore probably of the brain.

If the back is broken (dislocated), or the spinal cord is cut through by the knife or by disease, all parts below the point of injury are paralyzed, the power of sensation and voluntary motion being entirely lost. Dr. Hunter mentions a case in which the spinal cord of a man was severed by injury; when irritation was applied to the lower extremities they jerked violently, the man being quite unconscious of the irritation and the consequent motion. In this case the *spinal cord* acted as an *independent* centre of motion.

Course of the Motor Impulses.—*M. Brown Séquard* has shown that the *fibres* of the *anterior* or *motor* nerves pass up the spinal cord and *decussate* or cross at the lower part of the *medulla oblongata*. (See 2, Fig. 80.) If, therefore, a section of one half

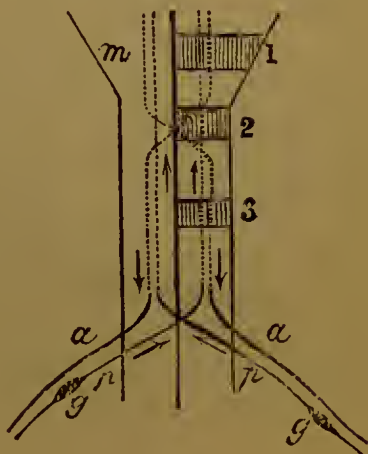


Fig. 80. — Diagram showing Course of Sensory and Motor Nerve Fibres.

a. Anterior or motor nerve fibre.
p. Posterior or sensory ,,
g. Ganglia on posterior nerves.
m. Medulla oblongata.

of the cord be made at this point, the power of *movement* will be lost by the *muscles* of *both sides* of the body. If the section be made a little higher, as at 1, Fig. 80, the power of movement will be lost by the muscles on the *opposite side* of the body only. If, on the contrary, the section be made a little lower, the muscles on the *same side* only will be *paralyzed.*

Course of the Sensory Impressions.—*M. Brown Séquard* has also shown that the *fibres* from the *posterior* or *sensory* nerves, immediately or very shortly after entering the spinal cord, cross the *median* line and enter the *grey* matter on the *opposite* side of the cord. It therefore follows that if one half of the cord were severed, as in the former case, at 1, 2, or 3, Fig. 80, that the power of *sensation* would be lost on the *opposite side* of the body, while that on the same side would remain perfect. It also follows that if the cord were divided *longitudinally* into two lateral halves, the power of *sensibility* would be entirely destroyed through the whole of the body.

The Spinal Nerves consist of thirty-one *pairs* of nerves (see Fig. 75), which emerge from the spinal cord, pass through the *intervertebral foraminæ* (See Figs. 55 and 59) of the backbone, and are distributed to the various parts of the body, communicating to them the powers of *sensation* and *motion.* Each spinal nerve contains two roots—an anterior or *motor* nerve and a posterior or *sensory* nerve, which are separated as they emerge from the cord by the *ligamentum denticulatum;* these roots unite to form a single nerve trunk as they pass through the *intervertebral foraminæ,* then subdivide, giving off branches which ramify through the system. They are arranged in pairs, according to the part of the *vertebral column* from which they emerge, as follows:—

Cervical nerves	. .	8 pairs	31 pairs.
Dorsal ,,	. .	12 ,,	
Lumbar ,,	. .	5 ,,	
Sacral ,,	. .	5 ,,	
Coccygeal ,,	. .	1 ,,	

The four upper pairs of cervical nerves unite to form the two *cervical plexuses* which give off nerves of motion and sensation to the adjacent parts; the four lower cervical pairs form the two *brachial* plexuses. The *median* nerve gives off *motor* branches to the arm, and *motor* and *sensory* branches to the hand, thumb, and fingers, as far as the ring finger. The *ulnar* nerve supplies *motor* branches to the adjacent muscles, and *sensory* nerves to the palm of the hand and the little finger: the pain consequent on striking the *funny* bone is due to the *ulnar* nerve. The *phrenic* or *motor* nerve of the diaphragm is derived from the cervical plexus. The *intercostal* nerves supply the walls of the chest and the adjacent parts. The *lumbar* plexus is formed by the union of the four upper pairs of lumbar nerves; the *sacral* plexus by the union of the fifth lumbar and the four upper *sacral* nerves. The largest nerve trunk in the body, the *sciatic* nerve, is derived from the *sacral* plexus; it gives off the *tibial* nerve: it is the seat of that painful disease *sciatica*. The *obturator* and *crural* nerves also supply the upper leg and knee.

Function of the Spinal Nerves.—The spinal nerves simply act as *conductors;* the *anterior* or *motor* nerves act *centrifugally*, conveying the *nervous force* by which *muscular contraction* is produced *outward;* the *posterior* or *sensory* nerves act *centripetally*, conducting the sensory impressions *inward* to the brain, where they give rise to consciousness or sensation.

When a current of electricity is passed through the *upper* portion of a severed nerve trunk it excites a feeling of *pain;* when it is passed through the *lower* portion of the nerve it produces *convulsive* movements. Section of a nerve root causes the paralysis of all those parts supplied by that *nerve trunk*.

The Sympathetic Nervous System, also termed the organic or ganglionic nervous system, consists of a series of about thirty *ganglia*, united chiefly

by a network of *grey* or *gelatinous* nerve fibre. It is connected with the cerebro-spinal system by white nerve fibre.

TABULAR VIEW OF THE CHIEF GANGLIA OF THE SYMPATHETIC SYSTEM.

The cranial ganglia .	Comprising the *nervi molles* at the base of the brain.
Four facial ,, .	Ophthalmic ganglion, connected with the nerves of the eyeball; the spheno-palatine, with the palate; the naso-palatine, with the nose; the otic, with the ear; and the submaxillary, with the nerves of the tongue and salivary glands.
Cervical ,, .	Superior, connected with the nerves of the pharynx, tongue, and thyroid body. Middle, with the nerves of the thyroid body and larynx. Lower, with the nerves of the heart and lungs.
Dorsal ,, .	Five upper, with those of the œsophagus, trachea, bronchi, and aorta. Seven lower, with the two splanchnic nerves, terminating in the solar plexus.
Lumbar ,, .	With those of the aorta and the arteries of the pelvic viscera.
Abdominal ,, .	Two *semilunar ganglia*, forming the *solar plexus*. Renal plexus, derived from the splanchnic nerves of the solar plexus.
Sacral ,, .	Four or five small ganglia of the pelvis.
Coccygeal ganglion .	The ganglion impar, in which the two rows of prevertebral ganglia unite.

The sympathetic system may be more generally divided into—1, the *isolated* ganglia and nerves of the viscera, the chief of which are the *cardiac*, *solar*, and *hypogastric* plexuses; 2, the *prevertebral* ganglia and

their connecting gelatinous nerve cords, which form a double chain of ganglia a little in front on both sides of the vertebral column; 3, the *ganglia* of the *posterior* roots of the *spinal cord.*

Certain involuntary organs, as the heart and intestines, are furnished with special ganglia, which have been termed *intrinsic* ganglia.

The sympathetic nerves are collected principally about the arteries and bloodvessels.

Function of the Sympathetic Nerves.—The sympathetic nerves are supposed to preside over, and, to a certain extent, to regulate, the *organic* functions of nutrition, digestion, secretion, &c., as the cerebro-spinal nerves regulate the animal system. They probably adjust and harmonize the action of respiration with that of digestion, circulation, &c., so that in a state of health the various organs perform their duty symmetrically. Their influence over the organs of nutrition is most likely exercised through the *contractile* power they exercise over the walls of the minute *arteries* and the *capillaries.* It is found that if a sympathetic nerve trunk be divided, the minute arteries which it supplies with nerves become enlarged, their coats yielding to the pressure of the blood, which they are unable to withstand, in consequence of the *nervous influence* being withdrawn, an excess of blood forces itself into the vessels, producing *congestion.* If the sympathetic nerves connected with the ear of a rabbit be cut, the bloodvessels immediately swell, becoming *congested*, and the part grows warmer. In this way certain parts, as the eye, become ulcerated, in consequence of injury to the nerves connected with them. The sympathetic nerves also bring the various organs of the body into relation with the *cerebro-spinal* system, and therefore under the influence of the

passions and emotions. Thus the heart of a living person might be touched and handled without the individual's being conscious of it, since it is but scantily supplied with *cerebro-spinal* nerves; but it is readily influenced by joy, fear, and anxiety, through the medium of the *sympathetic* nerves, with which it is abundantly supplied.

Reflex, Excito-motor, or **Diastaltic** actions (from L., *re*, back; and *flecto*, I bend: and Gr., *dia*, apart; and *stello*, I send) are effected independently of the *will*, and therefore of the mind. For the performance of these actions a *centre*, as a *ganglion* or the *spinal cord;* an afferent, *centripetal*, or sensory nerve; and an efferent, *centrifugal*, or motor nerve, are necessary.

The *afferent* fibres receive the *impression*, which they *convey* to the *ganglion* or *spinal cord;* the spinal cord sends back, through the medium of the *efferent* nerve, a *motor* impulse, which excites *movements* in the *muscles*, to which the *fibrils* of the latter are distributed.

The *winking* of the eyelids, the movements of *respiration*, *coughing*, *sneezing*, *swallowing*, *vomiting*, *peristalsis*, and *defecation* are all instances of *reflex* action. The *instinctive* actions of the lower animals are also regarded as *reflex*. Certain *nervous* diseases, as *hysteria*, *chorea* (St. Vitus's dance), *epilepsy*, infantile *convulsions*, *tetanus*, &c., are characterized by well-marked spasmodic *reflex* actions. Some poisons, as *strychnine*, kill by the violent *reflex* action they excite. The *mucous* membrane of the alimentary canal is very sensitive to these impressions during *infancy*. Hence the presence of an orange pip, or of caraway seeds, may cause death by convulsions or *reflex* action. (See pages 44, 50, 88, 115, and 216.)

Some *reflex* actions are attended with *sensation*, as the sudden withdrawal of the hands or feet from the contact of a burning object, the closing of the eyes tightly when dirt gets into them, &c. These are sometimes described as *sensori-motor* or *consensual* actions. *Habit*, by accustoming certain organs to combined ac-

tion, enables them to perform various movements *automatically* or unconsciously—that is, without the special exercise of the mind, as in walking, playing tunes on musical instruments, &c.; thus approximating them to the class of *reflex* actions.

A Ganglion (Gr., a knot), or nervous centre, consists of a small mass or knot of nerve *vesicles*, traversed by a network of *tubular* nerve *fibre*. (See Fig. 98.)

The functions of the *mesophale* probably resemble those of the *medulla oblongata*; those of the *optici thalami*, *tubercula quadrigemina*, and *corpora striata* are most probably connected with *sensation*.

THE ORGANS OF THE SENSES AND THEIR FUNCTIONS.

The organs of the senses consist essentially of arrangements by which *nervous fibrils* are spread out to receive *impressions* through the agency of certain *media*, which impressions they *convey* to the *sensorium* at the base of the brain, where they give rise to sensation.

Physiologists usually describe *five* senses, but it is now generally admitted we also possess a *sixth* sense. They are as follows:—Touch, taste, smell, hearing, sight, and, lastly, a *muscular* sense, by which we are enabled to judge of the *weight* or *resistance* of bodies.

Sensation may be *impaired* or *lost* by the injury or destruction of the organ of sense, of the nerve by which it is connected with the brain, or of the brain itself.

The Sense of Touch, which is but an exaltation of *common sensation*, is the most rudimentary and widely extended of the senses. Its chief seat is the skin (See pages 254, 255), the *sensory* nerves of which are chiefly derived from the *posterior* roots of the *spinal* nerves; their ultimate fibrils, in general, ter-

minate in the *papillæ* previously described. In certain parts the *sensibility* is intensified by the *tactile* bodies, resembling the Pacinian corpuscles previously referred to in Fig. 51 (page 256). A, represents the body of the corpuscle, consisting of 30 to 60 distinct concentric laminæ or capsules; B, E, the interior cavity into which the nerve tube passes; C, its stalk, consisting of modified *neurilemma;* D, the nerve tube, passing up the stalk to the axis of the capsule. Considerable difference of opinion as to their structure and functions prevails among physiologists.

The Sense of Taste resides chiefly in the *tongue*, but is not entirely confined to that organ; the *soft palate*, the *arches* of the *palate*, and the *fauces* participating, though much more feebly, in that function.

The *tongue* is the principal organ of *taste* and *speech;* it is almost entirely composed of *muscular* fibre; it has a *dorsum* (back), tip, edge, or border, and is divided by a *median* line, on its upper surface, into two symmetrical halves. Its exterior is lined with *mucous* membrane, covered with *epithelium*, which becomes thick and matted or *furred*, when the stomach is disordered. Its upper surface is covered with *papillæ*, which comprise *three* varieties:—1. *Filiform* (threadlike), which are most numerous. 2. *Fungiform* (mushroom-shaped). 3. *Circumvallate* (from L., *circum*, round; and *vallo*, I dig), which consist of a central *mound* or club-shaped process, surrounded by a circular *excavation*, trench, or furrow. The number of the latter, which are situated in two oblique rows at the base of the tongue, does not usually exceed eight or ten. The three varieties just described are termed *compound* papillæ; they are covered by smaller papillæ termed *secondary;* the latter are also termed *simple* papillæ.

The *papillæ* and surface of the tongue are supplied

with nervous fibrils from the *lingual* or *gustatory* branch of the *fifth* cranial nerve, which constitutes the *special* nerve of *taste*. It is also supplied with fibrils from the lingual branch of the *glosso-pharyngeal* nerve (of common sensation).

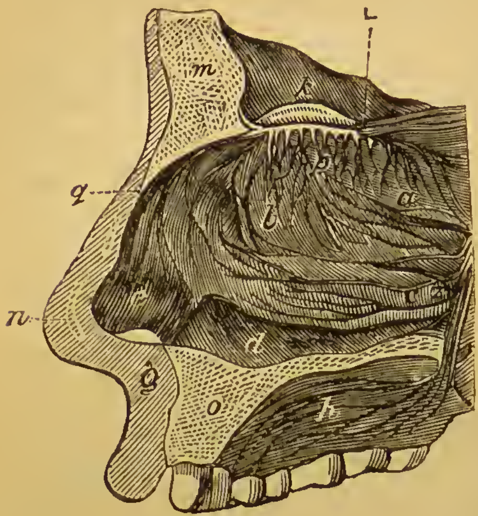
The ninth *cranial* or *hypoglossal* nerve, the *motor* nerve of the tongue, is distributed to its *muscular* substance.

The Sense of Smell is seated in the *nervous filaments* of the *mucous* membrane which lines the upper part of the nasal cavities. By it we become conscious of the presence of *odoriferous* particles in the atmosphere. The immediate organ of smell, situated at the roof of the nose, consists of an arrangement by which the *odoriferous* particles are brought into contact with the *fibrils* of the *olfactory* nerve.

The Nose is a triangular-shaped organ, comprising two symmetrical cavities, which are bounded on the exterior by bony and cartilaginous walls (the two nasal and upper maxillary bones), and separated internally in the *median* line by a bony and cartilaginous *septum*. The interior of these cavities is lined with a *fibro-serous* membrane, termed the *pituitary* or *Schneiderian* membrane. The olfactory *nerves* leave the olfactory *lobes* of the cerebrum, pass through the *cribriform* (sieve-like) plate of the *ethmoid* bone (which forms part of the roof of the nose), run between the fibrous and the mucous layers of the *Schneiderian* membrane, and ultimately ramify in the *mucous* membrane which forms the inner lining of the nasal *fossæ*. The *fossæ* or cavities of the nose open *exteriorly* by the two anterior *nares* or nostrils, and *posteriorly* (into the *pharynx*) by the two posterior *nares*.

The lining membrane of the nose is also freely supplied with nerves of common sensation. The nasal cavi-

ties are rendered somewhat labyrinthine by the superior, middle, and inferior *turbinated* (twisted) bones; the interior surfaces are thus greatly increased, so that the cool odour-laden portions of the atmosphere are warmed up to a temperature approximating to that of



a, *b*, *c*, *d*. Schneiderian membrane, lining the wall of the right nasal cavity; also showing nerves of common sensation.
e. Alæ of right nostril.
g. Upper lip.
h. Palatal nerve.
k. Olfactory lobe.
L. Cribriform plate of ethmoid bone of skull.
m. Frontal bone.
n. Nasal cartilage.
o. Upper maxillary bone (right).
p. Filaments of olfactory nerves.
q. Nasal bone.
z. Trifacial nerve.

Fig. 81.—INTERIOR OF THE NOSE.

the body before they are brought into contact with the *olfactory filaments*. These cavities also communicate with *sinuses* (cavities) in the *frontal*, *malar*, and *sphenoid* bones. Cold air blunts the sense of smell. The common affection termed "cold in the head" also blunts the sense of smell by increasing the quantity of the mucous secretion, and temporarily thickening the *mucous* membrane. Considerable difference of opinion exists as to the immediate cause of smell, some physiologists contending with much force that its immediate *physical* cause is the *chemical*

action of the *oxygen* of the air on the particles of the *odoriferous* substance.

The Ears, or the organs of hearing, which are placed one on each side of the head, consist of arrangements by which the fibrils of the *auditory* nerve (a branch of

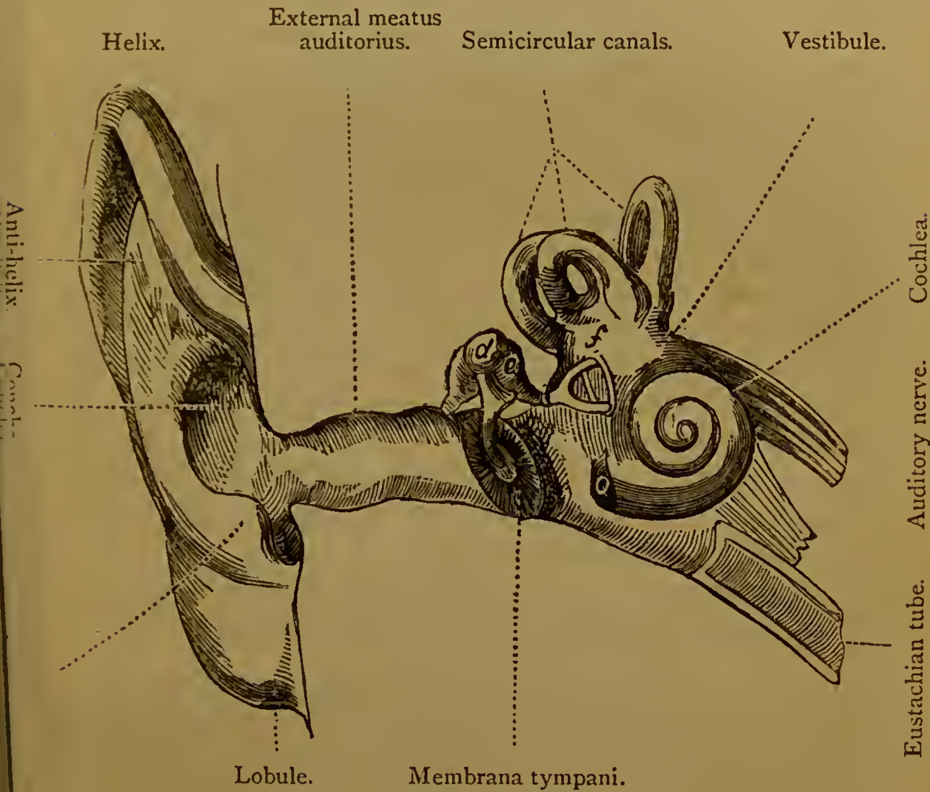


Fig. 82.—General View of the Human Ear.

d. Head of *malleus*, or hammer-bone.
e. *Incus*, or anvil-bone.
f. Fenestra *ovalis*.
o. Fenestra *rotunda*.

the 7th cranial nerves) are spread out to receive *vibratory* impressions transmitted from the air. Physiologists

divide it into three portions:—1, the external ear, comprising the *pinna*, or auricle (the outer expanded visible portion commonly denominated the ear), an external opening or auditory canal (the *meatus auditorius externus*); 2, the *tympanum*, or middle ear, an irregular cavity traversed by a chain of *ossicles* (the *malleus*, *incus*, and the *stapes*), which connect it with the labyrinth; 3, the inner ear, or *labyrinth*, which comprises the *vestibule*, *cochlea* (snail's shell), and *semicircular* canals: the outer, or bony labyrinth includes a *membranous* labyrinth, the interior of which is filled with a clear fluid termed the *endolymph;* the *space* between the *bony* and the *membranous* wall is filled with a clear fluid termed the *perilymph.* The membranous labyrinth takes the general form of, but is much smaller than, the *bony* labyrinth; its vestibular portion is expanded into two sacs—a smaller, the *saccule;* and a larger, the *utricle.* The *saccule* and the *utricle* contain small roundish masses of crystalline grains of carbonate of lime, termed *otolithes*, or *otoconia* (earstones, or ear powder).

The *tympanum*, or middle ear, communicates with the mouth by means of the *Eustachian* tube.

The *pinna*, the various portions of which are shown in the diagram (see Fig. 82), consists of *cartilage* and *integument;* the skin lining the inside of the auditory canal is studded with *sebaceous* and *ceruminous* (wax) glands. The *membrana tympani* separates the *external* from the *internal* ear; the *fenestra ovalis*, through which the vibrations of the stapes are transmitted to the nerves of the labyrinth, is covered by a membrane; the *fenestra rotunda* is also covered with a membrane which facilitates the production of vibrations in the internal ear. The interior of the bony *labyrinth* is lined with fine *fibro-serous* membrane. The *cochlea* has a central *axis* (the *modiolus*), round which a plate (the *lamina spiralis*), partly *bony* and partly *membranous*, winds about 2½ times, dividing the tube into two *spiral canals:* the whole arrangement very closely resembles a snail's shell. The

vestibule forms the *rudimentary* part of the ear, being found in all animals who possess special organs of hearing.

The *vibratory* particles, or *sound waves* of the atmosphere, enter the external or *auditory* canal, strike against and put the *membrana tympani* into *vibration;* it puts the chain of *ossicles* of the middle ear into vibration; they transmit their motion to the membrane of the *fenestra ovalis*, which communicates it to the *fluid* contained in the labyrinth; the fluid transmits it to the network of the *auditory nerve*, which is spread over the walls of the *membranous* labyrinth and the *lamina spiralis* of the cochlea; and the nerve conveys the *impression* to the brain (the sensorium), where it develops the *sensation* of sound. The sensation of hearing sometimes originates in the brain itself without the intervention of the organs of hearing; it is then termed *subjective.*

The Auditory, or soft portion of the 7th cranial nerve, is distributed to the inside of the *membranous* labyrinth (more especially to the *saccule* and the *utricle*), and to the *lamina spiralis* of the *cochlea.*

The Sense of Sight, by means of which we are brought into relation with the external world through the medium of *light*, is seated in the *eyes.*

The Eyes are organic *optical* instruments, by which the light is *collected*, brought to a *focus*, and thrown on to a *nervous screen*, on which it produces an *inverted* image of objects placed before it, as in the case of an ordinary magic lantern. It is supplied with certain mechanical fittings and appendages—*muscular*, *tendinous*, and *glandular*,—by which it is moved, cleaned, and *adjusted* with great accuracy. (See Fig. 83.) Sight does not take place in the *eye*, but in the *brain.*

Structure of the Eye.—The eye comprises the

eyeball and contents. The *eyeball* is about 1 inch antero-posterior (from front to back) diameter, and 9-10ths of an inch in lateral diameter. It consists

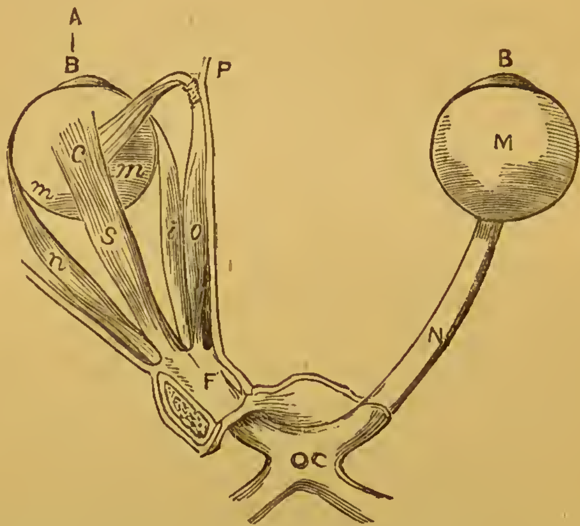


Fig. 83.—THE EYES AND THE MUSCLES OF THE LEFT EYEBALL.

A B. Line showing direction of the *axis* of vision.
B. Cornea.
M *m m*. Globe of the eye (sclerotic coat).
C S. Super *rectus* muscle (*attolens*).
i. Internal *rectus* muscle (*adductor*).
n. External *rectus* muscle (*abductor*).
o. Superior *oblique* muscle (*trochlearis*).
P. Pulley, or tendinous ring through which the *trochlearis*, or pulley muscle, works.
F. Bony wall of the optic foramen.
N. Optic nerve.
O C. Optic commissure.

of three coats, encloses three humours and two muscles, and is supplied with *nerves* and *arteries*. (See Fig. 84.)

Coats of eyeball.	Refracting humours.	Muscles.
1. Sclerotic, cornea (outer).	Aqueous.	Ciliary.
2. Choroid, iris, ciliary processes.	Crystalline (lens).	Iris.
3. Retina.	Vitreous.	

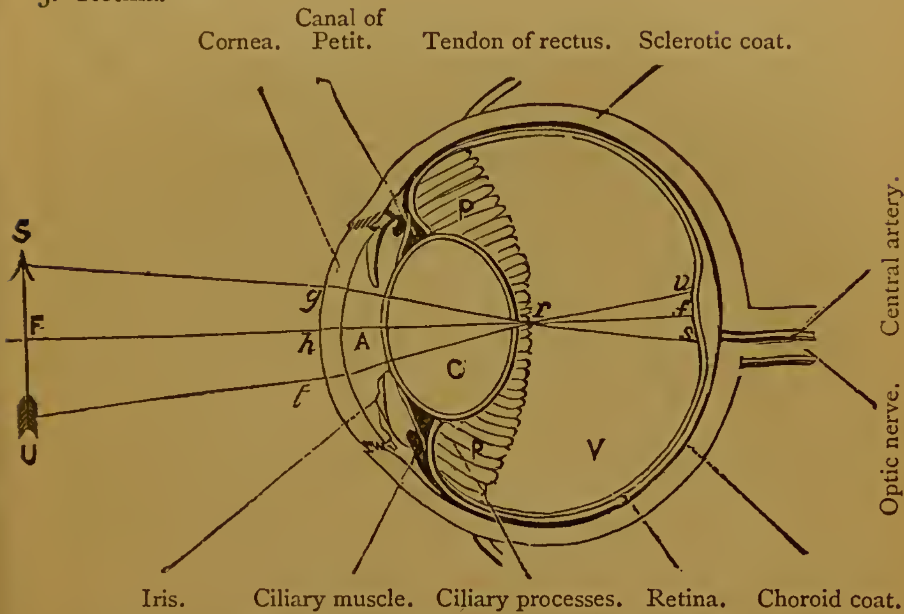


Fig. 84.—Vertical Section of the Human Eye.

A. Aqueous humour.
C. Crystalline lens.
V. Vitreous humour.
P. Ciliary processes.
S F U. Arrow.
u f s. Inverted *image* of arrow.

r. Focus.
S *g*, F *h*, U *t*, rays of light *before* refraction.
g r s, and *t r u*, *refracted* rays, which pass through the *pupil* or opening in the *Iris*.

The Sclerotic Coat (from Gr., *skleros*, hard) is the thick, tough, fibrous, *opaque* membrane which forms the outer covering (the *white*) of the eye. (See Fig. 84.) It cuts like a piece of leather. The *globular* form of the eye depends on this coat. The *sclerotic* coat is absent in the front of the eye, leaving a *circular* opening, and is pierced behind by the *optic* nerve, to which it is attached like an apple to its stalk. It consists chiefly of *white fibrous* tissue.

The Cornea (from L., *cornu*, horn) is the transparent *concavo-convex* lens which fits into the *anterior* opening in the *sclerotic* coat. It is nearly *circular*, and resembles a watch-glass, fitting into and projecting from the ball of the eye as the glass does from a watch. It consists chiefly of dense laminated *fibrous tissue.* (See Fig. 84.) It is usually more *convex* in children than old persons, and in the *short*-sighted than the *long*-sighted. It forms a sort of *window* to the eye, sometimes becoming *opaque* through inflammation or disease, and producing blindness. It is supplied with *nerves*, and becomes very *sensitive* when inflamed.

The Choroid Coat (from Gr., *chorion*, the outer skin of the egg, and *eidos*, shape), or *middle* coat (see Fig. 84), is only 1-200th inch thick, and consists of a delicate *vascular* coat, and an internal *pigmentary* layer, consisting of *hexagonal* cells, arranged like a neatly fitted mosaic pavement, and charged with dark *brown* or black *pigment* cells. The *black* colour of the interior of the eye, as seen through the pupil, is due to these *cells ;* they are either absent or deficient in *albinoes*, whose eyes, as seen through the *pupil*, are therefore of a *pinkish* colour. The apparent *function* of the *pigment* is to absorb the *surplus* light which would otherwise interfere with perfect vision. This coat lines the whole of the interior of the eye, excepting the back of the cornea, where it joins the *ciliary ligament ;* it then bends in, forming about sixty folds or *rays*, termed the *ciliary processes.*

The Ciliary Ligament is a narrow whitish fibrous ring which surrounds the *iris*, and connects it with the *sclerotic* coat.

The Iris (from L., *iris*, rainbow) is a thin, delicate, circular *curtain*, having a circular contractile *perforation* (the *pupil*) at its centre, which *regulates* the admission of the *light* to the eye. (See Fig. 84.)

It consists chiefly of *areolar* and *elastic* tissue, supporting capillaries, nerves, and pigment cells ; it also contains a small quantity of radiating and circular *muscular* fibre. It is attached to the *cornea* by its outer margin, and is suspended in the *aqueous* humour. The colour and variety of appearance of the eyes of different individuals are chiefly due to this organ. The *iris* divides the space between the *lens* and the *cornea* into two *chambers*, termed respectively the *anterior* and *posterior* chambers of the eye.

The Retina (from L., *rete*, a network) is the third,

inner, and most important *tunic* of the eye. It consists chiefly of an exquisitely delicate network of *nervous fibrils*, which are continuous with, and form an expansion of, the *optic* nerve. The *optical images* caused by the *light* which enters the eye are received on this membrane, and originate those impressions which, conveyed to the brain by the *optic* nerve, produce sight. The two most remarkable features of the *retina* are the macula lutea, or *bright spot of Sömmering*, and the *optic pore*. The former is in the line of most perfect vision; at its centre is a little depression, the *fovea centralis* (from L., *fovea*, a pit), formerly termed the *foramen centrale:* the latter, the *optic pore*, is blind, images falling on it not being perceived by the brain; at this point the *optic nerve* and *arteria centralis* enter, and the *veins* leave the eye.

According to modern physiologists, the *retina* comprises eight distinct layers, as follows, beginning from within :—

Layers of Retina.

1. Glassy limitary membrane.
2. *Fibres* of optic nerve.
3. Layer of *nerve cells*.
4. Finely granular grey layer.
5. Inner granular layer.
6. Intermediate fibrous layer.
7. Outer granular layer.
8. Layer of *bacillæ* (transparent rods), forming *Jacob's* membrane.

It has been estimated that the mind is capable of recognizing an image on the retina 1-34,500th of an inch in diameter. It has also been calculated that an *impression endures* on the *retina* about one-eighth of a second: hence, if a lighted stick be moved round quickly in a small circle, it will present the appearance of a *luminous* ring; hence, also, the phenomena of the *thaumatrope*. The apparent *size*

of a body depends on the *angle* of vision. Some persons are unable to recognize certain colours; this defect is termed *colour-blindness*: its exact cause is unknown.

The Aqueous Humour (from L., *aqua*, water) is the clear limpid fluid which fills the space in the front of the eye between the *crystalline lens* and the inner surface of the *cornea*. It consists of 98 per cent. of water and 2 per cent. of solid, chiefly of chloride of sodium (common salt). Its quantity does not in general exceed 4 or 5 drops. When lost by wounds it is quickly replaced; it is most probably secreted by the *vessels* of the *iris* and of the *ciliary processes*.

The Crystalline Lens or Humour in man is a clear, transparent, crystal-like, double convex, circular lens, about 1-3rd of an inch in diameter, and 1-5th of an inch in thickness. It lies exactly in the *antero-posterior* axis of the eye, separating the *aqueous* from the *vitreous* humour. It is the most important *optical* part of the eye. It is homogeneous to the naked eye, but when boiled or hardened by alcohol, exhibits a peculiar *laminated* and *fibrous* structure, very much resembling that of an onion. This lens sometimes becomes *white* and *opaque*, producing the disease termed *cataract*, and consequent blindness. Surgeons partially relieve this blindness by cutting through the coats of the eyeball, and *extracting* the *lens*, or by passing a needle through the coats of the eye into the lens, and forcing it down below the *pupil*, so that it shall no longer obstruct the light. The lens is enclosed in a firm, structureless, brittle, elastic, transparent membrane, termed the *capsule* of the lens. It is retained in its position by a membrane termed the *suspensory ligament* of the lens. A circular passage (the *canal of Petit*) exists between the margin of the lens and the sus-

pensory ligament, which is supposed to permit of the *alteration* in the *shape* and *position* of the lens required for its proper *adjustment.* (See C, Fig. 84.)

The Vitreous Humour or body (from L., *vitrum*, glass) is the largest *lens* or *humour* in the eye. It consists of a perfectly transparent, thin, jelly-like, *albuminoid* fluid, enclosed in an extremely thin, delicate, transparent membrane, termed the *hyaloid* membrane (from Gr., *hyalos*, glass), and fills 4-5ths of the globe of the eye. It is *convex* or spherical, except in front, where it is hollowed out into a saucer-shaped cavity to receive the back of the *crystalline* lens. The *hyaloid* membrane lines the *retina* and the back of the *crystalline lens*, and, according to some writers, sends off delicate *lamellæ* or processes into the interior, which divide it into cells or spaces, which are filled with the clear fluid just described. (See V, Fig. 84.)

This fluid consists of about 98·4 per cent. of water, and about 1·6 per cent. of solids, chiefly albumen and common salt.

Nature of Light.—Light is one of the *imponderables;* but whether it consists of corpuscles, undulations of ether, or is a mere variety of chemical or physical action, is not yet definitely determined. It moves at the rate of 191,500 miles per second. It always travels in *straight* lines when passing through the same *medium*, and when passing *perpendicularly* from one medium into another; but when it passes *obliquely* from one medium into another, its course is *broken*, and it is bent out of a *straight* line, or, in other words, it undergoes *refraction* (from L., *re*, back; and *frango*, I break). When rays of light pass through a *convex* lens, or magnifying glass, they are bent out of their course, brought to a *focus* (from L., *focus*, a point), and made to cross each other, thus producing an *inverted* image, as illustrated by the arrow, Fig. 84.

The *optical* parts of the eye act upon *light* very similarly to the *telescope* and the *camera obscura*, and, like them, require special means of *adjustment.*

The Appendages of the Eye comprise the *eyebrows*, *eyelids*, *conjunctiva*, and the *lachrymal* apparatus, including the lachrymal gland and sac, and the nasal duct.

The Eyebrows consist of *musculo-cutaneous* arches or ridges over the eyes, which are more or less studded with hairs. They shade and protect the eye. The hairs arrest the perspiration which sometimes streams down the forehead, and would otherwise flow into the eyes. They contain fibres from the *occipito frontalis*, the *orbicularis palpebrarum*, and the *corrugator supercilii* muscles.

The Palpebræ, or Eyelids, are two thin, flexible, moveable covers or lids for the protection of the front of the eyeball. Each eyelid contains a framework of *fibro-cartilage*, termed the tarsal cartilage, and consists (passing from without inwards) of very loose skin, areolar tissue, fibres of the orbicularis muscle, tarsal cartilage, fibrous membrane, and of an inner layer (next to the eyeball) of *mucous* membrane, the *conjunctiva*. The tarsal cartilages contain a number of *sacculated tubular* glands, termed the *Meibomian* glands. The edges of the eyelids are also fringed with a row of hairs (the eyelashes), which help to shade and protect the eye.

Lachrymal Apparatus.—The lachrymal fluid, or the tears, are secreted by small glands, lodged in depressions at the upper and outer angles of the orbits. After washing the surface of the eye they escape at the opposite angle through the *puncta lachrymalia* into the lachrymal *canals;* thence into the lachrymal *sacs;* and thence into the *nasal ducts*, which discharge them into the nose. The minute *structure* of the *lachrymal glands* resembles that of the *salivary* glands.

Muscles of the Eyebrows and Eyelids.—The principal muscles of the eyebrows and eyelids are the *orbicularis palpebrarum*, a circular or *sphincter* muscle, which surrounds the eye and closes the eyelids; the *levator palpebræ*, which *raises* the eyelid, and is the direct *antagonist* to the latter; the *corrugator supercilii*, which draws the eyebrow downwards and inwards, and produces the vertical wrinkles in the forehead (it also produces the expression of grief); and the *tensor tarsi*, which draws the eyelid down into the globe of the eye.

The Muscles which move the Eyeball (see Fig. 83) are the four *recti* (straight) muscles, and the *superior oblique* muscle, which spring from the back of

the *orbit*, near the *optical foramen* (by which the optic nerve enters the orbit); and the inferior oblique muscle, which lies directly under C S, Fig. 83, and springs from the floor of the orbit.

The *superior* rectus, or *attolens* muscle (S), moves the eye *upward;* the *inferior* rectus rolls it downwards; the *internal* rectus, or *adductor* (*i*), rolls it *inwards* towards the nose; the *external* rectus, or *abductor* (*n*), turns the eyeball *outwards;* the *superior oblique* (*trochlearis*, or pulley) muscle (*o*), which passes through a *loop* of tendon (P), (that acts the part of a pulley), rotates the eye *outward* and *downward;* the *inferior oblique* muscle, which is the *antagonist* of the latter, turns the eye *outward* and *upward.* When the two *oblique* muscles act together they *rotate* the eye on its *antero-posterior* axis.

The Adjustment of the Eye to different objects and distances is effected, according to some physiologists, by the four *recti* muscles of the eye, which, by contracting *simultaneously*, alter its *antero-posterior* diameter and increase the *convexity* of the *cornea.* It is, however, most probably effected by the ciliary muscle (see Fig. 84), the contraction of which increases, and the relaxation diminishes, the *thickness* and the *convexity* of the *crystalline* lens, and brings it nearer the cornea. The *iris* also assists by regulating the admission of light. (See "Crystalline lens.")

Myopia (from Gr., *muo*, I close; and *ops*, the eye), or short sight, is generally caused by the too great *convexity* of the *cornea*, or *crystalline lens.* The rays of light are brought to a *focus* too quickly; hence *indistinct* images of distant objects are formed on the *retina.* It is corrected by the use of *concave* spectacles.

Presbyopia (from Gr., *presbus*, old), or long sight, is in general caused by the flatness or *deficient* convexity of the *cornea*, or *crystalline* lens, which produces inability to adjust the eye to minute or near objects. It is corrected by the use of *convex* spectacles.

Single Vision.—No certain explanation of these phenomena is known. Probably but one object is seen, because the image produced in each eye is formed on a similar spot of the *retina*, and that consequently *similar* and *equal* impressions being *simul-*

taneously conveyed to the *brain*, but one perception is excited in the mind.

Erect Vision.—It has been suggested that an object appearing *erect*, while its image on the retina is *inverted*, is caused by the *decussation*, or crossing, of the fibres of the *optic* nerve before they enter the *brain*.

Binocular Vision (from L., *bini*, two; and *oculus*, an eye). —Bodies are said to appear *solid* because seen by the two eyes simultaneously, each eye receiving a slightly different picture, which the mind combines into the *notion* of *solidity*. It is, however, doubtful whether this is really a sufficient explanation of the *phenomenon*, since some landscape painters, with but one eye, cultivate their art with great success.

THE TISSUES, OR STRUCTURAL ELEMENTS, AND THE MEMBRANES.

The branch of biological science which treats of the microscopic structures, or the *elementary tissues*, is termed *Histology*. (See page 8.)

The principal tissues are *White fibrous* tissue; *Yellow elastic* tissue; *Areolar*, *Cellular*, or *Connective* tissue; *Adipose* tissue; *Cartilage*, *osseous* tissue; *Dentine*; the *Muscular* tissues; *Grey* and *White nervous* tissue; and the *Epithelial* tissues.

White Fibrous Tissue consists of parallel, wavy, flexible, but inextensible, tough, and inelastic fibres (resembling a skein of silk); the diameter of its fibres has not been determined, though fibres not exceeding 1-20,000th of an inch in diameter have been observed. It contains but few nerves or

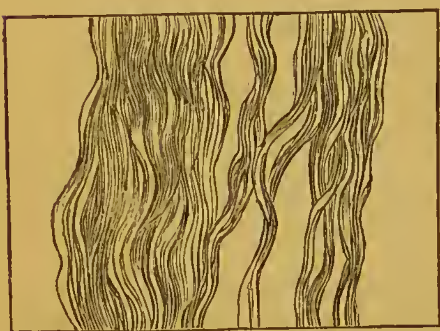


Fig. 85.—White Fibrous Tissue.

bloodvessels. It forms—1, ligaments; 2, tendons; 3, membranes, as the *periosteum*, *perichondrium*, the *sclerotic* coat of the eye, and the *dura mater*, which lines the skull. It is so tough that 1,000 lbs. force are required to rupture the *tendon Achilles*, even after death. It has very little vitality, but is readily repaired; when boiled in water it yields *gelatine*.

Yellow Fibrous or Elastic Tissue consists of minute, cylindrical, yellowish, extensible, flexible, and highly elastic fibres. It is nearly as elastic as india-rubber; is but slightly *vascular* or *sensitive;* is not acted upon by dilute acids; and does not yield *gelatine* on boiling. The yellow fibres of which it is composed vary from 1-10,000th inch to 1-4,000th inch in diameter; when broken, by being stretched, the ends of the fibres curl up, giving them a peculiar and characteristic appearance.

Fig. 86.—Yellow Fibrous Tissue.

This tissue is found nearly pure in the *ligamentum nuchæ* of quadrupeds; in the *ligaments* at the back of the vertebral column, by which its power of flexion is increased; in the *vocal cords*, and other *ligaments* of the *larynx;* also in the *epiglottis*. It forms the *middle* coat of the *veins* and *arteries:* a peculiar variety of it, having a flattened and *perforated* appearance, found in some of the arteries, is termed *fenestrated* membrane (from L., *fenestra*, a window). It sometimes forms *homogeneous membrane*, as in the inner layer of the *cornea* and the capsule of the *crystalline lens*.

Areolar Tissue (from L., *area*, an open space), or connective tissue, is the most widely diffused tissue in the body. It is a very flexible, extensible,

elastic, whitish substance, possessing but feeble sensibility; it is slightly vascular, and consists of a network of bands of *white* and *yellow fibrous* tissue, containing numerous *areola*, or spaces, from which it derives its name. It is very abundantly diffused through the body, forming the *matrix* of the skin, and connecting the various tissues and organs together, and, when condensed, forming sheaths or *investing* membranes, as the *fasciæ* of the muscles and the *neurilemma* of the nerves. It is sometimes termed *cellular* tissue. When treated with dilute acetic acid, numerous microscopic oval-shaped bodies, termed connective tissue corpuscles, are rendered visible.

Fig. 87.—AREOLAR TISSUE.
Showing *areolæ*, or open spaces in dried tissue.

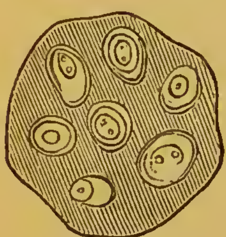


Fig. 88.—SECTION OF CARTILAGE.

Showing intercellular *matrix*, or blastema, and embedded *nucleated* cartilage *cells*.

Cartilage. — *Articular*, or true cartilage, is an extensible, elastic, firm, flexible, tough, glistening,

opalescent substance, varying from a bluish or pearly white to a yellowish white colour. It consists of a homogeneous *matrix*, in which are embedded numerous *nucleated* cells, termed cartilage *corpuscles*, which vary from 1-1,300th to 1-900th of an inch in diameter. It contains neither nerves, bloodvessels, nor lymphatics, and is nourished by the *liquor sanguinis*, which exudes from the adjacent bloodvessels. The ends of the moveable bones are tipped with cartilage, which lessens friction by its *smoothness*, and diminishes concussion by its *elasticity*. When boiled it yields *chondrin*. The cartilage of which the skeleton is formed in early life is termed *temporary cartilage*, in consequence of its becoming *ossified*. The soft cartilage of the *ears*, *eyelids*, the *epiglottis*, *larynx*, *intervertebral* pads, and *costal* and *nasal* cartilages, possess a *fibrous* matrix; it is therefore termed *fibro-cartilage*. It is slightly vascular, and yields *gelatine* on boiling.

Adipose Tissue consists of clusters of *nucleated* vesicles or cells, 1-800th to 1-300th of an inch in diameter, consisting of transparent, homogeneous, *structureless* membrane, which is not more than 1-20,000th of an inch thick. The original form of the cell is spherical, but it becomes hexagonal by compression, like those of the honeycomb. Each cell is surrounded by a *capillary* loop, and its interior filled with a yellowish unorganized *fluid*. *Adipose* tissue neither contains nerves nor lymphatics.

Fat.—The yellowish, homogeneous, unctuous *fluid* which is secreted into and fills the interior of the fat cells is termed *fat*. It consists of *two* solid proximate principles, *stearine* and *margarine*, combined with a fluid constituent termed *elaine*. Fat congeals or solidifies on cooling after death, forming the *suet* of the butcher. The formula $C_{10}H_9O$ indicates with approximate accuracy the general composition of fat.

Fat gives roundness and beauty to the human figure, helps to

pack and protect the various organs, retains and supports the animal heat, and forms a store of respiratory food always available for the wants of the system when required.

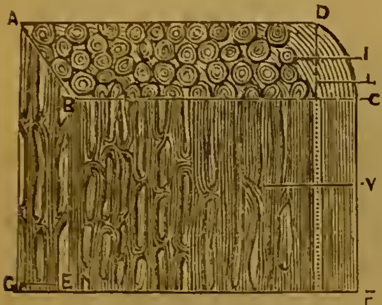
Osseous Tissue, Osteine, or Bony Tissue.—If a very thin shaving of compact bone be examined under a microscope it is found to be made up of little

Fig. 89. — Microscopic Structure of Bone (Transverse Section), Showing—
An *Haversian* canal, represented by the dark central space ;
The *lacunæ*, forming concentric rings round the *Haversian* canals ;
The *canaliculi*, which radiate from the *Haversian* canals through the *lacunæ*, giving the latter a spider-like appearance ;
The bony *lamellæ*, marked off by the *concentric* rows of *lacunæ*.

systems, termed Haversian systems, containing—1, a central canal, termed an *Haversian* canal ; 2, concentric solid *laminæ;* 3, concentric rows of *lacunæ*, separating the solid *laminæ;* 4, minute radiating tubes, termed *canaliculi*, which radiate or diverge from the *Haversian* canal, and connect it with the various circular rows of *lacunæ*. All true bone manifests this structure.

The Haversian canals are minute oval or circular canals discovered by the anatomist *Havers*. They vary from 1-2,500th to 1-200th inch in diameter, their average diameter being about 1-500th inch ; they are about 1-120th inch distant from each other. They contain the bloodvessels by which the interior of the bone is nourished.

The Lacunæ, Bone cells, or Bone corpuscles, as they have been variously termed, consist of little cells or furrows, 1-1,800th inch long, 1-3,600th inch wide, and 1-5,400th inch thick. These cells, with the *canaliculi* radiating through them, present a very spider-like appearance.



A, B, C, D. The surface as seen in *transverse* section.
B, E, F, C. The surface as seen in *longitudinal* section.
I. A single *Haversian* system, with its central canal.
G, V. *Haversian* systems cut longitudinally.
L. *Lamellæ* near the surface, destitute of *Haversian* systems.

Fig. 90.—Longitudinal Section of Bone.

The Canaliculi are exceedingly minute tubes, 1-20,000th to 1-1,200th inch wide. They probably aid the processes of absorption and nutrition.

The Matrix of bone consists of *fibrous* tissue, in which the earthy constituents of *true* bone are deposited.

Composition of Bone of Man (Berzelius).

Animal matter	31·11
Phosphate of lime	59·14
Phosphate of magnesia	1·20
Carbonate of lime	6·32
Fluoride of calcium	2·23
	100·00

Dentine, or tooth tissue, in many respects closely resembles bony tissue, but differs from it in containing more earthy matter, and being destitute of *true Haversian* canals. It contains about 72 per cent. of *earthy* and 18 per cent. of *organic* matter. When examined under the microscope it presents the appearance of a yellowish white, solid substance, having an apparently *fibrous* structure. This fibrous

appearance is due to the presence of minute characteristic *tubuli*, which open and run from the pulp cavity (see page 42) to the surface of the tooth. These tubuli *bifurcate*, or divide into *twos*, towards

Fig. 91.—Microscopic Section of Dentine.

Showing intertubular substance, and *tubuli* branching *dichotomously* towards the surface.

the surface of the tooth, where they anastomose with the *canaliculi* (small canals) of the tooth-bone. They evidently constitute the media by which the tooth is nourished.

Muscular Tissue comprises two varieties—*striated* (striped) and *non-striated* muscular fibre.

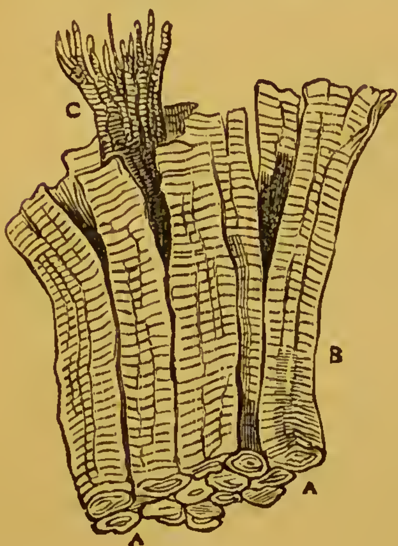


Fig. 92. — Portion of Voluntary Muscle.

A A. Ends of primitive *striated* fibres.
B. Side of fibre, showing transverse *striæ*.
C. Primitive *fibre* split into *fibrillæ*.

The former enters into the structure of the *voluntary* muscles and the *heart*, the latter into the structure of the *organic* or *involuntary* muscles.

Striated Muscular Fibre.—If a piece of flesh or muscle be examined under a magnifier, it will be seen to consist of parallel *fasciculi*, or bundles of *fibres*, bound together by sheaths of *areolar* tissue. If *one* of these *fibres* be examined carefully under a more powerful microscope, it will be seen to consist of still more minute parallel pale yellowish *primary* fibres, termed *fibrillæ*, which have a beaded or *striated* appearance, from which this class of muscular fibres derives its name and character. These *fibrillæ* form the ultimate or *primitive* structural element of *striated* muscular fibre; they are about 1-400th to 1-350th of an inch in diameter. Each muscular fibre is invested in a delicate sheath or covering of *areolar* tissue, termed the *sarcolemma*. The *fibres* may be separated *transversely* into little *discs*, as well as *longitudinally* into *fibrillæ*.

PLAN OF STRUCTURE OF VOLUNTARY MUSCLE.

- Muscle
  - Fasciculi
    - Fibres
      - Fibrillæ.
      - Sarcolemma.
    - Areolar tissue.
    - Capillaries.
    - Nerves.
  - Fascia.

The *fibrillæ* are composed of muscular *fibrin* or *syntonin*.

The **Sarcolemma,** or Myolemma (from Gr., *sarx*, flesh; *muon*, a muscle; and *lemma*, a husk), is a transparent, colourless, tough, elastic, but very delicate, and in general *structureless* membrane, which forms the tube or *sheath* by which each *striated* muscular

fibre is invested. It is supposed to consist of modified *areolar* tissue.

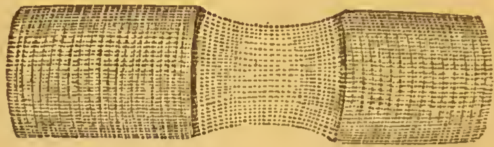


Fig. 93.—SARCOLEMMA.

A *primitive* muscular fibre broken across, showing the untorn *sarcolemma* connecting the fragments.

Organic or **Non-Striated** Muscular Fibre consists of minute *nucleated fusiform* (spindle-shaped) cells, united into minute flattened bands of a pale yellowish colour, 1-3,000th to 1-2,000th inch in diameter. Some anatomists suppose these bands to interlace together, while other anatomists deny such

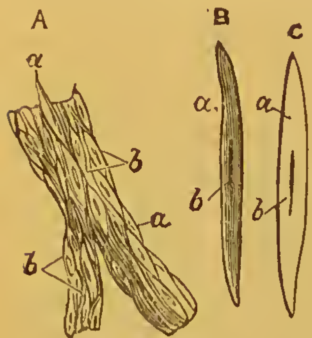


Fig. 94.—NON-STRIATED MUSCULAR FIBRE.

A. Band of *fibre* composed of *fusiform* or spindle-shaped cells, showing *a a*, the *cells*, and *b b*, their *nuclei*.
B. A single *cell* more highly magnified.
C. A single cell treated with acetic acid to render the elongated *nucleus* more distinct.

to be the case, and regard them as parallel. *Unstriated* fibre is destitute of *sarcolemma:* when treated with *nitric* acid it splits up into its *primitive* structural elements, which consist of spindle-shaped cells with oblong *nuclei:* these cells have been termed *contractile fibre* cells. Unstriped muscle is found in the coats of the *alimentary* canal, and of the *bladder*, *veins* and

arteries, *gall*-bladder, excretory *ducts*, and larger *lymphatics*, and in the *iris*, the *ciliary* muscle, *trachea*, *bronchi*, and the *skin*.

Nerve-Tissue comprises three kinds — *white tubular* nerve-fibre, as in the cranial and spinal nerves; *grey gelatinous* nerve-fibre, as in the sympathetic system; and *vesicular* nerve-substance, as in the interior of the brain and the ganglia.

White Tubular Nerve-Fibre.—If a trunk of the spinal nerves be examined with a microscope, as

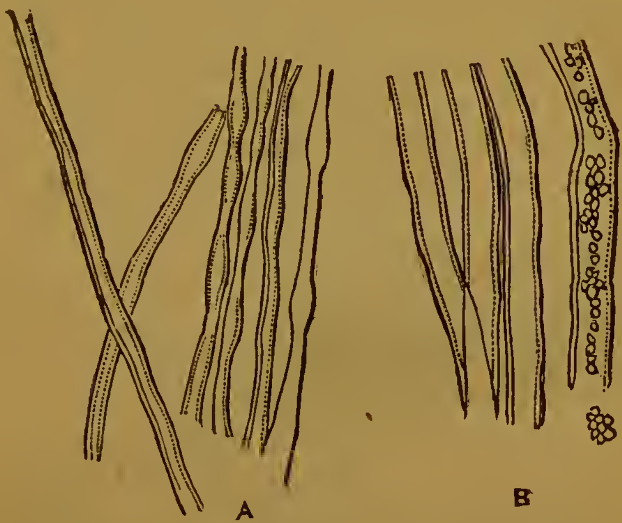


Fig. 95.—STRUCTURE OF NERVE-TUBES.

Tubular nerve-fibres :—A, from a nerve-trunk ; B, from the substance of the brain.

Showing external transparent tube, *central* band, and intermediate *white substance of Schwann.* The interior of the tube to the right has become slightly grumous or granular.

in the case of the muscle previously mentioned, it will be seen to consist of bundles of *white fibres* or *tubuli*, on an average of from 1-4,000th to 1-2,000th

inch diameter, held together by a sheath of white *areolar* tissue; one of these nerve-bundles is termed a *funiculus* (from L., *funis*, a bundle). These *funiculi* form larger bundles termed *fasciculi*, which are invested in a sheath. The *tube* or *sheath* which invests the *nerve-tubule* is termed the *neurilemma*, and corresponds with the *sarcolemma* of *primitive* muscular fibre.

If one of these *primitive* nerve-tubules be examined carefully with a more powerful microscope, each tubule will be seen to consist of—1, an inner or *central* band, termed the *axis cylinder*, central band, or band of Remak; 2, an *outer* transparent, homogeneous, elastic tube of great delicacy, sometimes also termed the *neurilemma;* 3, an intermediate *whitish* or *medullary* substance, of a different composition and refractive power, termed the *white substance of Schwann.* It

Fig. 96.—PLAN OF SECTION OF A NERVE-FIBRE.

has been suggested that during life these substances may be blended, and only separated after death by a sort of *coagulation.* The parts just described may be seen very clearly if the nerves be broken by stretching. Little oil-like globules appear in their interior when they are immersed in ether.

Neurilemma (from Gr., *neuron*, a nerve; and *lemma*, a husk).—Some confusion exists among writers as to the use of this term, some applying it to the homogeneous *external* sheath of the *primitive nerve-tubule*, others to the sheaths of the smaller

funiculi, while others, again, apply it indiscriminately in both cases. It consists of a very delicate variety of *areolar tissue.*

A Nerve consists of a *bundle* of *white tubular* fibres enclosed in a sheath.

Gelatinous Nerve-Fibres, or *Grey Nerve-fibres*, belong to the *sympathetic* system, are exceedingly minute, flattened, soft, greyish fibres, containing numerous cell-nuclei. Acetic acid dissolves the *fibres*, but leaves the *nuclei.* These fibres range between 1-6,000th and 1-4,000th inch in diameter, being therefore smaller than the *white* nerve-fibre.

Nerve Vesicles, Vesicular Neurine, or *Nerve*

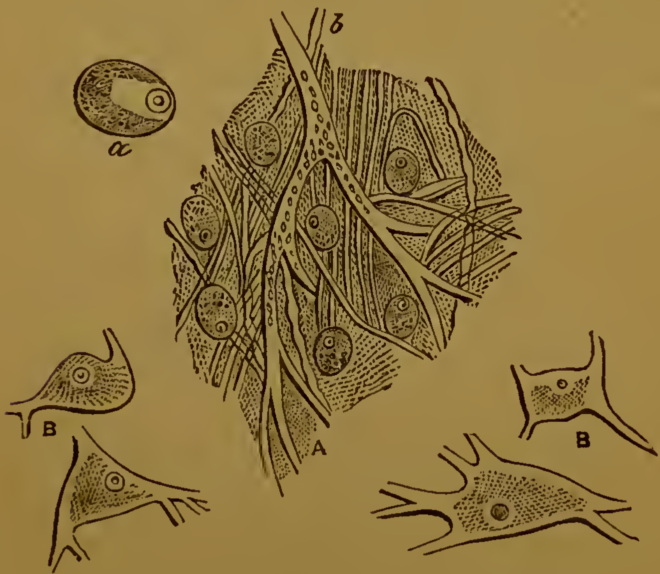


Fig. 97.—VESICULAR NERVE-SUBSTANCE.

A. Portion of a *ganglion* consisting of *nerve*-cells and fibres.
a. One of the ganglion cells more highly magnified.
b. A capillary vessel.
B. *Caudate* or *stellate* nerve-cells, or nerve-corpuscles.

Corpuscles, consist of *nucleated* cells of various forms, designated, according to their respective shapes, as *spheroidal*, *pyriform*, or pear-shaped, *caudate* (tailed), and *stellate* (star-shaped). These bodies enter into the structure of the *ganglia*, and are therefore sometimes termed *ganglionic cells* or *corpuscles*. The *cortical* substance of the brain and the interior of the *ganglia* consists principally of *vesicular* nervous matter. The *nucleolus* in the *nucleus* forms a most characteristic feature of the nerve-cell.—(See Fig. 97.)

The nerve-cells probably *generate*, and the nerve-fibres simply *conduct*, nervous force.

Serous Membranes consist of—1, an *external* layer of *compact areolar tissue*, less abundantly supplied with bloodvessels than the corresponding lamina in *mucous* membrane; 2, a middle layer of *basement membrane*, similar to that of *mucous* membrane; 3, an inner single layer of *tesselated epithelium* on its *free* surface. They are always kept moist by a liquid termed the *serous fluid*.

The *serous membranes* form closed sacs, which line the interior of the great cavities of the head and trunk. The principal serous membranes are the *arachnoid membrane*, which lines the cavity of the skull; the *pleura*, which lines the lungs and cavity of the chest; the *pericardium*, which lines the heart; and the *peritoneum*, which lines the interior of the cavity of the *abdomen*. The *serous sacs* are closed sacs, one half of which is folded or tucked into the other, so as to form, as it were, an inner lining which rubs against the outer portion. The *outer* layer, which is attached to the walls of the cavity in which it is placed, is termed the *parietal* layer; the inner receives the organ to the surface of which it is everywhere attached, forming its lining membrane, and is termed the *visceral* layer. Their inner, free, or *epithelial* surfaces, which rub together, are moistened to reduce friction. When these membranes become inflamed, they tend to throw out large quantities of a liquid termed *coagulable lymph*, which sometimes, as in pleuritis, joins the two walls together, producing what are in surgical

language termed *adhesions*, which seriously interfere with the freedom of motion natural to these parts. When the serous fluid is secreted in morbid quantities, it collects in the cavities, constituting *dropsy*, *water on the head*, &c.

Serous Fluid is a thin, transparent, colourless, albuminous fluid, resembling but thinner than the *serum* of the blood, which is secreted and effused on the surface of the serous membranes for reducing friction between their surfaces.

Synovial Membranes form similar but smaller *closed sacs* than those formed by the *serous* membranes, which they much resemble. The walls of the *synovial* sacs line the two ends of the bones of the moveable joints, and are *reflected* back so as also to line the fibrous capsule passing from one bone to the other. The interior of the sac is abundantly supplied with a fluid termed *synovia*, which lubricates the joint and lessens friction. The structure of the synovial membranes resembles that of the serous membranes.

Synovia is a transparent, yellowish, glairy, viscid, albuminous fluid, resembling but thicker than white of egg. It lubricates the joints and some tendons, to allow them to glide or play over each other with the least possible friction. It resembles the *serum* of the blood, but is thicker.—(See page 282.)

Mucous Membranes are somewhat *complex* structures. They consist of—1, an *exterior* layer of compact or consolidated *areolar tissue*, continuous with the ordinary subjacent *areolar* tissue, by which it is attached to the adjacent surfaces: this layer is well supplied with *bloodvessels*, though but *sparingly* with *nerves*; 2, a middle layer of structureless *basement membrane*; 3. an *epithelial* layer, on its inner or free surface, consisting of a single or multiple layer of *epithelial cells*. They are moistened by *mucus*, and possess the ordinary physical qualities of areolar tissue.—(See page 223.)

Mucous membrane is *simple*, as in the smooth lining membranes of the nose and air passages; or *involuted* and compound, as in the stomach, where it is folded into minute pits or depressions, termed *follicles;* and in the intestines, where it is folded into little projecting, short, hair-like bodies, termed *villi. Villi* and *follicles* are merely arrangements for increasing the *absorbing* or *secreting* surface of the mucous membrane.

Basement Membrane is a very thin and delicate, transparent, structureless membrane, which forms the middle layer of the skin, serous and mucous membranes. It affords a basis for the attachment of the *epithelial* layer, and is permeable by fluids in the processes of *osmosis* and *endosmosis.*

Epithelium Cells consist of microscopic nucleated cells, of various sizes and shapes, held together more or less firmly by a moist intercellular matrix or blastema, which line the inner or free surfaces of the *serous*, *mucous*, and *synovial* membranes, the free *secreting* surfaces of the glands (see page 222), and which compose the *outer* layer of the skin.

Their functions are—1, *protection* or defence, as in the skin and other organs, subject to contact or friction; 2, *absorption*, as in the *columnar* epithelium of the *villi* of the intestine, by which the chyle is absorbed; 3, *secretion*, as in the *glands;* 4, *cleansing*, as shown in the constant renovation and escape of the epithelial cells of the skin, the respiratory and the gastric mucous membranes.

There are four principal varieties of epithelial cells, —1, *squamous* or scaly, sometimes termed *tesselated* or *pavement* epithelium, as in the peritoneum, serous membranes, and conjunctiva, or lining membrane of the interior of the eyelid; 2, *columnar*, as in the *villi* of the intestines; 3, *ciliated*, or supplied with little hair-like processes, as in the trachea and air passages; 4, *spheroidal*, *polyhedral*, or *glandular*, as in the secreting portions of glands.

The epithelial tissues contain neither bloodvessels, nerves, nor lymphatics.

Fig. 98.—EPITHELIUM CELLS.

A. *Squamous* or scaly epithelium.
B. *Columnar* epithelium.
C. Ciliated ,,
D. Glandular ,,

Cilia (from L., *cilium*, an eyelash) are exceedingly minute, hair-like, *vibratory* bodies, which form fringe-like processes, attached to the *epithelium* cells that line the surface of the smaller *bronchial* tubes, the *nasal* cavities, *frontal sinuses* (in the skull), *lachrymal* ducts, *Eustachian* tubes, *velum palati*, *fauces*, *larynx*, &c. They are somewhat flattened and tapering, and vary from 1-13,000th to 1-500th of an inch in length. Their *function* is apparently to prevent the accumulation of viscid fluids, and to propel them towards their outlet. The vibratory motion of the *cilia* is ceaseless during the *life* of the *epithelium*, and they continue in rapid vibration some time after the *death* of the animal.—(See page 212.)

Functions of Mucous Membranes.—The mucous membranes line the *open cavities* of the body, including the respiratory, alimentary, and urinary cavities and passages. They act — 1, *defensively*, protecting those organs from the effects of friction and the irritation of the atmospheric air and other substances; 2, as organs of *secretion*, supplying a liquid by which their surfaces are kept continually moist, and by which the fluids necessary to digestion are elaborated from the blood; 3, as organs of *excretion*, constantly renewing and casting off epithelial cells which escape from the system.

Mucus is the transparent, structureless, colourless, slimy substance secreted and effused by the *mucous* membranes, as in the nose, mouth, &c. It usually contains cast-off epithelial scales. During inflammation of the mucous membranes it increases in quantity, becoming white, opaque, and more or less purulent, as in severe catarrh, or in "cold in the head."

CELLS—CELL DEVELOPMENT AND REPRODUCTION.

The most general *elementary* form of *organic* matter is that of the *cell.* At one time it was supposed that all the fibres and membranes of the animal body were

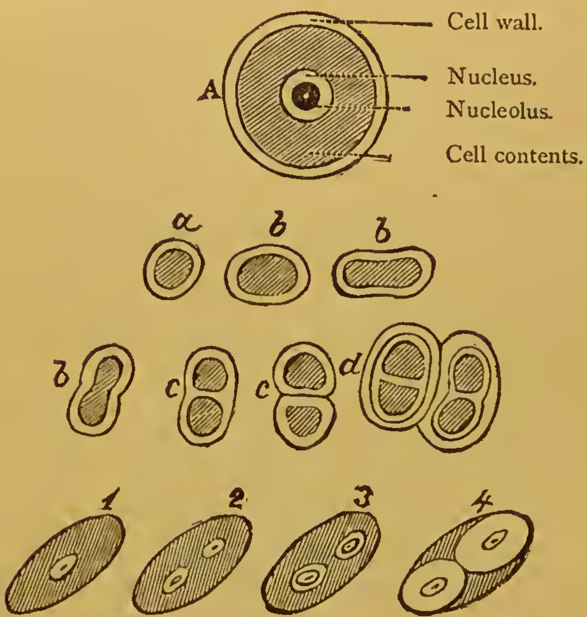


Fig. 99.—Showing Structure and Development of Cells.

A. Nucleated cell.
a, b, c, d. Formation of new cells by division of *cell.*
1, 2, 3, 4. Formation of new cells by division of *nucleus.*

formed out of *cells*, but this is now considered to be only partially true. The typical cell consists of the parts shown in the diagram, A, Fig. 99; but all these parts are not always present, or, at least, are not always distinguishable. The *essential* part of every perfect *cell* is its *nucleus*, which consists of *germinal matter*. (See page 218.)

A Cell may originate *de novo*, or it may arise from a *pre-existing* or parent cell. All cells originate in a fluid, *blastema*, or formative matter. When a *cell* originates *de novo*, molecules of solid substance are formed, which coalesce to form a *nucleus*, or central mass, round which a delicate membrane, or *cell wall*, consisting of formed material, is developed. This membrane is gradually *differentiated*, or separated from the nucleus by the intervention of fluid or granular substance, forming the *cell contents*. Little granules, termed the *nucleoli*, are also developed in the body of the nucleus. The *cell wall* is, in all cases, formed of *nitrogenous* or *albuminoid* matter.

Cells are formed out of *pre-existing* or parent cells by two different processes of spontaneous subdivision. 1. The *parent* cell first elongates; then contracts somewhat in the form of an hour-glass (see *a*, *b*, Fig. 99), and ultimately divides. The process of subdivision commences in the *nucleus*, which separates into *two* parts, a double layer of cell wall being formed about them at the point of separation. 2. The *nucleus* itself subdivides, a new *cell wall* being formed about each *segment* of the *nucleus*, a number of complete cells being thus formed in the *interior* of the parent cell. This process of subdivision of the nucleus or germinal matter may be carried on to almost any extent *in* the *parent* cell.

The cells, having attained *maturity*, may undergo

the following changes:—1. They *die* and *decay*, the cell walls *dissolving* away; or they may *burst*, discharging their contents, which constitute a *secretion*. 2. The *cells* may become charged with pigment, bony or other matter. 3. The *cell walls* may undergo transformations: by joining together endwise, their ends being ultimately absorbed, *tubes* may be formed; by the closing in of these walls *fibres* would be formed; by their becoming flattened and joining edgewise *membranes* would be developed; and by their throwing out radiating or *caudate* processes networks or *plexuses* of tubuli would be formed. Some physiologists believe that organic *fibres* may be formed *originally*—that is, without the intervention of cells—by a process of *fibrillation*, in which the molecules of *germinal* matter arrange themselves *primarily* in the form of *fibre*. The most perfect *elementary* cells usually met with in the body are the *epithelial* and *fat* and *nerve* cells.

All animals originate in cells. Certain cells, eggs, or *ova* (*germ* cells), which are developed in the ovaries of the female, possess a higher power of *differentiation* than ordinary cells: this higher power is only called into operation after fusion with other cells, termed *sperm* cells, which are developed in the bodies of males in organs specially set apart for that function. Unless the ovum or *germ* cell is brought under the influence of the *sperm* cell it *dies*, decays, and liquefies; but having received that influence its higher life is brought into play, and it undergoes a series of *metamorphoses*, by which it is ultimately developed into an organized being, resembling, in all its general characters, the parent from whom it sprang. These changes may be best observed in the development of the bird from the egg

during incubation; they only take place within certain temperatures, approximating to that of the body.

The following is a general description of the changes which take place in the *ova* (or eggs) of the mammalia during the development of the *embryo*:—

The *ovum* of a mammifer consists of an external membrane, the *zona pellucida*, or *vitelline* membrane, which encloses a granular yolk, the *germ yolk;* in the centre of the yolk is the *germinal vesicle* (the germ cell), containing the germinal spot. When the *ovum* becomes fertilized by the influence of the *sperm cell*—1, the *sperm cell* and *germinal vesicle* dissolve in the yolk; 2, the granular *yolk* commences a process of *segmentation*—first separating into *two* parts, these into *four*, the latter into *eight*, and so on until the whole is reduced to a mulberry-like mass of distinct *nucleated* cells; 3, this mulberry-like mass of cells becomes *differentiated*, forming into connective and muscular fibre, cartilage, bone, membrane, vessels, &c.; (*a*) an *elevation* forms on the surface, which gradually divides into a groove (the *primitive groove*); (*b*) the *lateral boundaries* of this groove extend *upwards*, forming the tube for enclosing the brain and spinal cord, and *downwards*, forming a tube for the alimentary canal, heart, and bloodvessels; (*c*) processes forming rudimentary limbs are given off from the sides.

In the earlier stages of development the *embryos* of all animals are very similar; in the later stages the parts acquire their *specialities;* and lastly, the *embryo* is converted into the form of the parent from which it originated.

Changes of Animal Existence.

1st stage,	A minute particle of *nitrogenous* matter.
2nd ,,	Develops into an *embryo* having the special type and construction of the parent.
3rd ,,	Is born, works, wastes, and renovates.
4th ,,	Dies.
5th ,,	Decomposes and returns to *inorganic* matter.

The offspring inherits the general appearance, form, and qualities, mental and physical, of its parent. Whatever *raises* the type of the parent improves its

offspring. On the other hand, whatever lowers the vigour, vitality, or the mental or physical qualities of the parent, deteriorates its offspring. Thus good and bad qualities alike are transmitted, and the sins of the fathers are visited upon the third and fourth generation. These facts constitute "the hereditary transmission of qualities." In this way mental *education*, or the cultivation of the *nervous* system, determines to the *succeeding* generation not only a larger amount of cultivated *knowledge*, but also what is of much greater importance, a higher degree of *intrinsic* mental power. In some instances the offspring more closely resembles its *grand*parent, or some remote predecessor, than its immediate parent: this phenomenon is termed *atavism*.

DEATH.

Death, or the *cessation of life* or *vital activity*, may be described as *Molecular*, *Local*, and General or *Somatic*.

Molecular Death (from L., *moles*, a mass; and *ule*, denoting small) consists of those series of disintegrations (or deaths) of the constituent particles of the tissues or organism which are incessantly taking place, and to which the development of the animal *heat*, the *muscular* and *nervous forces*, and the general phenomena of *life* are mainly due. These *destructive* changes are *perpetual* during life, but are compensated for or balanced by an equally *perpetual* series of *regenerative* changes, or births of new particles, by which the health and integrity of the tissues are maintained; just as a nation lives by new births, though the members composing it are continually dying off. *Molecular* has therefore been described as *perpetual death*.

Local Death.—Whatever stops the circulation of an organ or any of its parts, arrests nutrition, and causes their *death* or decay: this action frequently takes place in the natural course of life, as in the shedding of the milk-teeth; but it may also occur as a consequence of disease or injury. The decay and shedding of the milk-teeth (page 44) during childhood is caused by the growth of the permanent teeth, causing their crowns to press against the fangs of the milk-teeth, thereby closing the vessels by which they are *nourished.*

In man the epidermis or outer skin is being continually though slowly removed by a gradual process of desquamation (page 252); but some other animals, as the serpent, part with it periodically, or *cast the skin.*

Birds *moult* or cast their feathers periodically. Each feather is nourished by vessels which pass up the centre of the quill; the quill gradually thickens, contracts, and closing in upon the central bloodvessels, *cuts off* the supply of blood. The feather therefore *ceases* to be nourished, and is *moulted* or *cast off* as a dead product of organization. *Deer* cast their *antlers* from a similar cause, the deposition of *bony* matter at the base of the antler compressing and *closing* up the vessels, and consequently shutting off the *nutritive* supply.

Local death, however, sometimes results from disease or injury, as in cases of *sloughing* and *mortification.* When the *circulation* and consequent *nutrition* of a limb or organ are arrested by inflammation, pressure, the ligature of an artery, section or injury of the nerves, contusion, cold (frostbite), or from want of vigour in the circulation, it mortifies or dies and putrefies, the adjacent parts gradually *sloughing* or coming away in small portions, and an offensive and more or less putrid sore being formed.

If a splinter enters the skin it produces irritation and consequent inflammation of the part; the *liquor sanguinis* exudes, and by its pressure on the minute bloodvessels of the adjacent parts more or less completely *obstructs* the circulation and *arrests* the *nutrition* of the parts, producing a small wound or ulcer. This process illustrates in a lower degree what takes place during more serious inflammation, ulceration, and mortification.

General or **Somatic Death** (from Gr., *soma*, a body), or death of the whole body, formerly described as *systemic* death, is consequent on the *cessation of the circulation*, and is *usually* caused by the failure of one of *three* centres, which have therefore been denominated by *Bichat* the *tripod of life*,—viz., the *heart*, *lungs*, and *brain*.

Syncope (from Gr., *sun*, together; and *kopto*, I cut).—When the immediate *cause* of death is the failure of the *propulsive* power of the heart, death is said to result from *syncope*.

Asphyxia (See page 216).—When the immediate cause of death is obstruction to the flow of the blood by the *capillaries* of the *lungs*, death is said to be produced by *asphyxia*.

Coma (from Gr., *koma*, lethargy).—When death is caused by failure of the action of the *brain*, the animal dies in a state of *insensibility* or *unconsciousness*, the *heart* and *lungs* ceasing to act from the want of the necessary *nervous influence*. In the latter case death results from *coma*.

It may be produced by certain *poisons*; *ardent spirits*; by *physical shock*, as a fall or a violent blow on the abdomen; or by *nervous shock*, as fright, passion, excessive joy, &c.

Death also probably sometimes *begins* in the *blood* itself, under the influence of *fever* and other poisons, the centres of life previously described ceasing to act

because of the want of *vitality* in the blood; this has been termed death by *necræmia* (from Gr., *nekros*, dead; and *aima*, blood).

Rigor Mortis is the term applied to the stiffening of the body which ensues within a short period after general or *somatic* death; its exact *cause* is still matter of discussion among physiologists; it is generally attributed to the *tonicity* of the muscles, but some physiologists connect it with the *coagulation* of the blood. It forms a sort of demarcation between *general* and *molecular* death. After the *rigor mortis* the muscles soften, and putrefactive decomposition, the only sure *sign* of death, sets in.

Death from Old Age is consequent on the gradual *exhaustion* of the *vitality* of the system. During old age *nutrition* gradually falls more and more below *waste;* the animal heat is so reduced as to be greatly influenced by external cold; the brain and senses are greatly blunted, and the nervous power consequently greatly reduced; and the circulating current, which is exceedingly feeble, is at last brought to a stop by sheer *exhaustion of vitality*, and thus life is brought to a close by a quiet, *painless* death. This, however, but rarely happens; accident, misconduct, immorality, or disregard of *sanitary* laws, almost invariably determining *premature* death. There can be but little doubt that the human body, which is a collection of the simpler forms of organic existence, is capable like them of a certain duration of life, during which it passes through certain phases of *birth*, *growth*, *maturity*, and *decay*, and beyond which *period of duration* it is impossible to prolong it. But it is equally certain that the *vigour* of its life and the *period* of its duration are in general greatly *limited* by those premature *excesses* in which young people, just at the period when their constitutions are undergoing *consolidation*, are but too apt to indulge. We

cannot better conclude this solemn subject than with the following passage from Mr. Oliver Wendell Holmes's beautiful poem, "The Living Temple:"—

"O Father! grant Thy love divine
To make these mystic temples Thine!
When wasting age and wearying strife
Have sapped the leaning walls of life,
When darkness gathers over all,
And the last tottering pillars fall,
Take the poor dust Thy mercy warms,
And mould it into heavenly forms!"

APPENDIX.

The Columnar or **Bacillar** layer of the *retina* (Jacob's membrane) consists of a single layer of transparent, colourless microscopic *rods*, interspersed with *cones*, attached to nervous *fibrils*, and packed closely together side by side, "like the seeds of a sunflower." It was formerly supposed to receive and reflect the light *back* on to the fibrous network of the retina; but it is now supposed by Professor Kolliker to receive the primary *luminous* impressions, which it communicates to the *fibrils* of the optic nerve.

Blindness arising from loss of nervous power in the *retina* is termed *amaurosis.*

Ocular Spectra.—Look intently for a few seconds at a bright red wafer on a white background powerfully illuminated by the sun's rays; then turn the head away from the paper, and a *green spectral* wafer will be seen, showing that when the retina has been strongly impressed with a bright colour it tends to produce spectral impressions whose colours are *complementary* to those by which they were excited.

The Blind Spot in the Eye.—Place two *black* wafers

about 4 or 5 inches apart on a white background against the wall; then place yourself before the paper, and look fixedly at the paper; close the left eye, then move gently backward, keeping the eye fixed on the *wafers;* at a certain distance the *right-hand* wafer becomes *invisible*, but reappears on going nearer to or farther from the paper; at the point at which the *right-hand* wafer *disappears* its image falls on the *punctum cæcum* or *optic pore* of the *left* eye.

Sleep is the *functional* repose of the *cerebrum* and *sensory ganglia.* Where injury or accident has exposed the *brain* to view, it has been observed to be *quiet* and *motionless* during *sleep*, but to pulsate and throb vigorously during dreams, and in the waking state, especially during excitement. An average of seven to eight hours' sleep is required by those whose occupations involve much *mental labour* or *anxiety.*

Dreaming is caused by the partial activity of the *cerebrum* and *sensorial ganglia* during imperfect sleep.

Somnambulism (from L., *somnus*, sleep; and *ambulo*, I walk) is a peculiar state of *cerebral* activity, in which the sensorium is in a state of *repose* or *suspended* activity.

Functions of the Cerebrum (omitted from page 298).—The *cerebrum* is the seat of the *intellect*, emotions, and the will. When it is removed from the lower animals they lose their *memory* and power of *volition.* When it is very much below the ordinary size, the individual is deficient in mental power, and in most cases idiotic. When it becomes *softened* or *inflamed*, *idiotcy* or *delirium* sets in. The *intelligence* and the *reasoning* faculties are affected by *poisonous* or *intoxicating* agents, which act upon the cerebrum. (See pages 15, 292, 294.)

Venous Pulse.—The orifice of the superior *vena cava* is not supplied with a *valve*, the *weight* of the descending column of the blood acting as a *substitute.* Each time, however, the right auricle contracts, a backward pulsation, which is visible in the *jugular* veins of the neck, is produced, which is termed the *venous pulse.*

The Respiratory Venous Pulse (a fulness of the vessels of the neck distinct from that just described) is caused by the *pressure* on the vessels during the *contraction* of the chest in the act of *expiration.*

Questions given at the Examination for Science Certificates, November, 1865.

ANIMAL PHYSIOLOGY.

NOTE.—You are permitted to answer six only out of the following questions. *The values attached to the questions are equal.*

1. What are the chief constituents of the blood, and in what proportions do they occur?
2. How many sorts of "vessels" are there, and in what respects do they differ from one another?
3. Suppose that a blood corpuscle in the hepatic vein has taken the shortest route to reach that point from the right ventricle, through what organs, valves, and vessels has it passed?
4. Suppose that a particle of fatty matter, the product of digestion, passes from the small intestine to the superior vena cava by the shortest possible route, what course does it take?
5. How many salivary glands are there? Where are they placed, and what functions do they perform?
6. Describe the mechanism of respiration, and the changes which take place in respired air.
7. What is meant by the "contraction" of a muscle, and by what arrangements is muscular contraction made available to produce locomotion in man?
8. What are the different kinds of muscle, and what kinds of muscle are found in the following parts respectively:—the eyelid, the iris, the heart, the cheeks, the gullet, the intestine?
9. What are cilia? Where do they occur in man?

SECOND PAPER.

NOTE.—You are permitted to answer six only out of the following questions. *The values attached to the questions are equal.*

1. What are the general structure and arrangement of the parts of the brain?

2. Why are certain nerves termed cerebral, and what organs and parts of the body are supplied by those nerves?
3. What is the ultimate structure of nérvous substance as revealed by the microscope?
4. What is meant by the "irritation" of a nerve; and when a nerve is irritated, what takes place in the parts with which it is connected?
5. Where is the nervous apparatus of the sense of touch lodged, and how may the degree of the acuteness of that sense in different parts of the body be estimated?
6. Where is the organ of the sense of smell situated? Explain what takes place in the respiratory organs when one snuffs up an odour; and what is the use of that operation?
7. What is the ordinary temperature of the body, and how is that temperature kept up and regulated?
8. Describe the structure of any joint between bones freely moveable on one another.
9. How is the eye moved, and how are the eyelids raised and depressed?

NOTE.—*Three hours were allowed for each paper.*

Questions given at the Examination of Science Schools and Classes, 3rd May, 1865.

PAPER ON ANIMAL PHYSIOLOGY.

GENERAL INSTRUCTIONS.

Three hours are allowed for this paper.

You are only permitted to attempt eight questions.

You may select your questions from Series I., or from Series II., or from both.

The value attached to the correct answer of each question in Series I. is 10; and of each question in Series II. is 20.

N.B.—A full and exact answer will in all cases gain more marks than an inexact or incomplete one; though in the former case the question may be the more easy of the two, and have less value attached to it.

Series I.

1. What is the structure of bone?
2. Where does cartilage occur in the human body, and what is its structure?
3. What is the structure of the tissues called "epithelium" and "epidermis," and where do they occur?
4. What are cilia? Where are they found in the human body?
5. How many kinds of "corpuscles" are there in the blood, and what are their distinctive characters?
6. Describe the circulation of the blood.
7. Where is the liver placed; what is its secretion; and how is that secretion poured into the intestine?
8. What is the structure of the tissue called "striped muscle," and what are its properties?
9. Where is the brain placed, and what are the principal structural elements of which it is composed?
10. Enumerate the structures which enter into the composition of the eye.

Series II.

1. Enumerate and explain the action of the muscles of the eye and eyelids.
2. What is meant by the "adjustment" of the eye, and how is it effected?
3. Give an account of the structure of the ear.
4. What is the "pulse"? why is no pulse observable in the veins?
5. What glands secrete saliva or a similar fluid? what are the functions of the saliva?
6. What is "lymph"? Give a general account of the lymphatic system.
7. By what means are the products of digestion absorbed into, and the products of waste eliminated from, the blood?
8. By what conditions is the temperature of the human body determined?
9. Describe the mechanism of breathing, and the changes undergone by the air inspired and expired.
10. Give examples of purely motor, of purely sensory, and of mixed nerves; and describe the manner in which the motor and sensory fibres of the spinal nerves of the latter class become separated in the roots of the nerves.

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J. & W. Rider, Printers, 14, Bartholomew Close, London, E.C.